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Acoustic Transients of the Marginal Sea Ice Zone: A Provisional Catalog

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This report summarizes characteristics of selected Arctic acoustic transients. Acoustic sources are divided into biological (living animals) and physical (ice-related) categories. Acoustic characteristics include time series, spectrograms and sonograms. Also included are supporting environmental and biological data.

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ACOUSTIC TRANSIENTS OF THE MARGINAL SEA ICE ZONE: A PROVISIONAL CATALOG

I. INTRODUCTION

A. BACKGROUND

The Arctic Ocean and surrounding ice-covered seas comprise an inviting habitat for a wide variety of marine animals that produce underwater transient noises. Identification of these sounds is of interest to Arctic researchers and to the men in submarines who sometimes share this habitat with the long-term residents. Equally important are the natural underwater noises from the ice, the wind, and the earth. These too must be sorted out in any cataloging of the natural sounds of this environment.

Interest in the underwater noise of Arctic and sub-Arctic regions has considerably heightened in response to increased strategic importance of this region. *Transient* (noncontinuous) components of underwater noise have always concerned the sonar community, but the present emphasis on Arctic and nearby regions poses unique problems.

Biological Transients

The sources of Arctic and sub-Arctic biological transient noise are mostly marine mammals, but fishes and invertebrates also can be responsible. Biological sounds consist of broad or narrowband spectra from impulses, short tonals, or complex signals.

The earliest recordings of sounds from Arctic marine mammals were made in the 1950s by Americans. Since then much has been contributed by scientists from Canada, Denmark, and the Soviet Union. Overall, Arctic and sub-Arctic marine mammal species affect the underwater ambient noise in a broad spectrum from less than 20 Hz to more than 150 kHz.

Arctic biological and physical noise measurements have been made at ice camps, remote sensors, and in submarines. Each site has its advantages and disadvantages from the standpoint of data collection and application.

Depending upon location, species, accompanying behavior, and season

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of the year, biologics may dominate all other noise sources. Because of high source levels (*i.e.*, to 190 dB *re* 1 uPa, l m), frequent occurrence, and broad spectrum, marine mammal sounds often produce more Arctic noise than that from the ice canopy. The noise from a single large whale, or even one seal, may have *long duty* cycles. The additive effect of large groups (e.g., dozens of large whales, or hundreds of small whales or seals) often totally dominate the underwater noise.

The present study revealed that the total population of Arctic marine mammals is approximately 20 million individuals. Most of these inhabit the *marginal sea ice zone* (MIZ), but some species, such as ringed and bearded seals venture into the central Arctic. In addition to the contribution of underwater noise, Arctic marine mammals are of acoustical significance in other ways, since their behavior apparently includes active and passive sonar to navigate the Arctic ice.

Physical Transients, Arctic Ice, and Applications

Early studies of ice and other physical sources of Arctic underwater noise also were undertaken in the mid 1900s. These included on-site measurements in the marine environment, observations on frozen lakes, and indirect measurements of ice emission events from laboratory samples. Nations besides the United States, contributing to the scientific literature on physical sources of Arctic ambient noise, include Canada, Denmark, Norway, and the Soviet Union. Physical transient noise sources include:

(1) Thermal cracking of ice from changes in ambient air temperature (broadband spectra *re* sudden negative temperature gradient);

(2) Flexural cracking of ice from wind- or current-induced stress (broadband spectra *re* current or wind speed and direction);

(3) Crushing of ice by compressive stress (knocking, grinding and squeaking *re* over-ride, ridging, and rafting);

(4) Snow grain impact (pelting) directly on the ice surface or on compacted snow on the ice (broadband spectra *re* wind speed and direction);

(5) Underwater release of air from iceberg capsize (bubble spectra *re* water and air temperature, and glacial activity);

(6) Melt water and brine cascading through the ice (broadband drip spectra *re* ice and ambient temperature and age of ice);

(7) Man's activities including surface and submarine craft, icebreaking, seismic exploration, aircraft, and on-shore industrial activity coupled through permafrost (virtually unlimited spectra and waveforms *re* type of source).

The most commonly used boundary for the Arctic region is the Arctic Circle, at 66° 33' N latitude, marking the southern extent of continuous summer daylight. Another boundary (often used in zoology) is the 10°C isotherm that extends the demarcation south of Greenland into the North Atlantic; and in the Pacific, through the Bering Strait into the Bering Sea.

The Arctic Ocean itself is a unique ice-covered region. The area of the canopy grows in winter to nearly 8 million sq km. (comparable to the Atlantic Ocean, N of the 38th parallel). It shrinks to less than half that area in summer.

The MIZ may be loosely described as the area bounded by the outermost edge of sea ice and the outer boundary of the permanent ice pack, where ice cover is virtually 100%. The area of the MIZ is seasonably variable, hence the useful synonym for this region, *seasonal sea ice zone:* the seasonally ice-covered region between minimum and maximum extent of the ice.

Arctic ice has a variety of forms to include the core of permanent floating *pack ice* surrounded either by *landfast ice* clinging to the continental margins or unstable sea ice in the form of large *floes* or smaller broken pieces. In a given region, ice coverage may vary from full to occasional.

The *shear zone* between landfast and central pack ice is an area of physical stress and collision from wind and currents. Compressive stresses in the ice canopy are relieved by *pressure ridges* that may rise several meters above the ice surface. These ridges may have *ice keels* extending downward 50 m or more from the sea surface. Since ice cannot support significant extensional stress, large cracks, called *leads*, occur, exposing the open water. Leads may close rapidly

by refreezing or by a shift in the direction of ice-stressing mechanisms. A mere change in wind direction over just a few hours may be sufficient to open or close a lead, 1-km wide. All of these processes produce underwater acoustical noise transients from physical sources. To meet many of the biological needs in their respective life cycles, the animal species of the MIZ are closely involved with the ice around and over them.

The U.S. Navy's involvement in the Arctic is supported by a National Arctic Polar Region Policy, which emphasizes tactics, training, and optimization of existing and planned operations, while developing an adequate engineering technology. One of the key technological areas in this program involves acoustics, in particular acoustic transients. The present antisubmarine warfare (ASW) solution to transient detection and classification depends on highly trained human operators, of which there is a growing shortage. Consequently, the ASW R&D community is developing a computer-based automatic recognition that will aid the operator, prevent data overload, and reduce training requirements.

Specialized training material needs improvement to distinguish underwater acoustic transients from biological, ice-earth, and human activity. Sonar operators often report more false targets in Arctic regions, where the sonar background may contain more transient noise components of natural origin, compared with lower-latitude open waters.

Arctic marine research generally will experience unprecedented growth throughout the rest of this century. The exploration and development of the Arctic's vast petrochemical and other natural resources, the Arctic's effect on global weather and other atmospheric patterns, its political importance, and its challenge for research into new sociological, political, and industrial activities will form the basis of extensive new technical studies.

Format and Qualification

This catalog is a compendium of information concerning Arctic acoustic transients in two general categories:

Biological Transients: sources from living animals.
Physical Transients: sources from the water or ice.

The information is divided into three basic types:

> *Supporting Data*--descriptions of the transient origin, e.g., species Distribution, Numbers, Life History, or mechanisms of ice or other physical transients.
>
> *Transient Data*--a brief description of the sounds including known Dates, Locations, and Conditions of sampled recordings, features of the transient, and known Sources of Data, including that data not analyzed.
>
> *Transient Analysis*--examples of waveform, sonogram, or spectrum of sampled transients.

Although this catalog stresses biological sources in the MIZ of Arctic or sub-Arctic regions, no attempt was made to set rigid geographic boundaries, owing to the nature of the data. For example, if a given species occurs in both Arctic and temperate regions, but has not been acoustically recorded in Arctic waters, recordings from temperate regions may have been analyzed and presented. For example, the striped porpoise, *Stenella styx*, ranges from Greenland to Jamaica, and even into the southern hemisphere off West Africa. However, the only available recordings for this species were from temperate Atlantic regions.

No attempt was made to include all sounds of a given species, because the sounds are so diverse. For example, humpback and bowhead whales exhibit a format of sound production called "song", which is comprised of several different repeated complex components that may change in character and order over extended time periods. All marine mammals produce a wide variety of underwater sounds, but only a few could be represented here.

This study showed there are 31 species of "Arctic" marine mammals. The biological transients included in this provisional catalog represent these animals. Two pinnipeds (*i.e.*, seals and sea lions), the Baikal and Caspian seals, are limited to relatively small impoundments within the USSR and were not considered appropriate for inclusion. Two other marine mammals, Sowerby's and Steneger's beaked whales, may occur in cold temperate and sub-Arctic regions, but they are rarely seen and probably never knowingly recorded.

Several species included in this catalog are known by more than one common name, *e.g.*, Greenland right, bowhead, great polar, and Arctic right whale, all signify *Balaena mysticetus*. We generally employed the most popular common name. In a few cases more than one common name is used, because there is no preference.

At the end of the catalog is a listing of SELECTED REFERENCES where additional information may be found regarding many of these transient sources and the environments in which they exist.

B. OBJECTIVES

This catalog was intended to provide a common useful format to bring together a selection of scattered data. The intent is to present selected noise components and a description of their occurrence. The catalog is provisional in that it only contains examples of biological sources of transient noise in the MIZ oceanic regime, together with representatives of physical transients. This is the beginning of a data base that can be confidently isolated and identified.

Objectives of this report were to:

(1) Identify and obtain representative data sources of Arctic noise transients (noncontinuous underwater/ice acoustic noises),

(2) Analyze selected transients in terms of time (waveforms, time history displays) and frequency domains (spectra),

(3) Summarize acoustic characteristics of selected transients, and

(4) Assemble a catalog of the representative Arctic noise transients.

C. ACKNOWLEDGMENT

We thank Y. Yam (NAVSEA, PMS 409) for support of this work and in recognition of the importance of Arctic transient noise. Special thanks go to R. Doolittle (NRL) for information on acoustic transients and administrative assistance. C. Votaw (NRL) offered thoughtful comments on the manuscript. We are indebted to many

other scientists who recorded transients included in this catalog or that otherwise provided valuable information conveyed by publication or personally. Among these are I. Dyer (MIT), H. Kutschale and J. Kelley (U. of AK), H. Winn (U. of RI), R. Mellen (NUSC), A. Beal (NOSC), W. Schevill and W. Watkins (WHOI), G. C. Ray (U. of VA), B. Buck (PRL), F. Awbrey, A. Bowles, and associates (Hubbs Marine Center), R. Pritchard (Kent, WA), B. Mohl (Denmark), and A. Milne, J. Terhune, E. Mitchell, and I. Stirling (Canada). S. Ridgway (NOSC) kindly allowed us to use illustrations from his book, "Mammals of the Sea" (Charles C. Thomas Publisher), S. Crawley helped with assembly, and L. Key provided editorial assistance. The present work was supported through a prime contract to NRL from NAVSEA and a subcontract to Oceanographic Consultants, San Diego, CA.

W. C. Cummings (Oceanographic Consultants) collected and analyzed the recordings, and wrote the report; O. I. Diachok was responsible for project management and technical guidance; and J. Shaffer worked with the format and catalog.

II. METHODS

A. DATA SOURCES

We arbitrarily sampled characteristic sounds of selected available Arctic transient sound recordings.

The basic acoustical data consisted of selections from analog or digital magnetic tape recordings of underwater sounds in the field under natural conditions, or, in the case of some bioacoustic sources, from confined animals. None of the original data were recorded under aegis of this project. Recordings were furnished by one of us (W. C. Cummings, (WCC)), or by other investigators who had released them to us, the Navy, or the public domain.

A wide variety of receiving and recording instrumentation had been employed. For the most part, broadband hydrophones were used at depths down to 200 m, and magnetic, analog tape recorders were used after some method of signal conditioning, *e.g.*, amplification, attenuation, or filtering. Both direct and frequency-modulated (FM) recording were used. Only in some cases were calibrated systems employed, and none of the calibrate scales of sound intensity were carried through to the illustrations presented here. Hydrophones either were "hard wired" or they were part of sonobuoy systems. They were deployed from the ice or from some other surface platform, such as ice breaker, conventional ship, small boat, or landed helicopter. The data were obtained over many years, going back to the 1950s or as recently as 1987.

Numerous published and unpublished sources were used as bases for the SUPPORTING DATA (given only for bioacoustic transients) and TRANSIENT DATA, many of which are cited in the SELECTED REFERENCES section. Those sources included original data from the research of WCC and associates.

B. ANALYSIS

Virtually all signal analyses included in this catalog were done under support of this project. Sonograms (*i.e.*, voice prints) were produced by continuous spectral display of updated spectra, after

digitization and FFT. In all cases the updating rate was fast enough to show the major characteristics, but good resolution was not always possible for finer details or sounds of shorter duration. Project resources did not permit possible detailed analyses.

Spectrographs (power spectra) were made of most sound categories (*i.e.*, major types of sounds: a given species, or a specific physical mechanism such as ice cracking) by using a real-time spectrum analyzer (RTA) set to yield peak hold, "instantaneous", or averaged spectra. Choice of method depended on the temporal characteristics of the signal being analyzed. The same RTA was used to obtain waveforms of many of the signals. It was necessary to employ low-, high-, or bandpass filters with some of the transients in an appropriate method whereby spectra of the actual transients were not affected. Analyses were done in the narrowband (NB) mode, and a Hanning window was selected for all spectra.

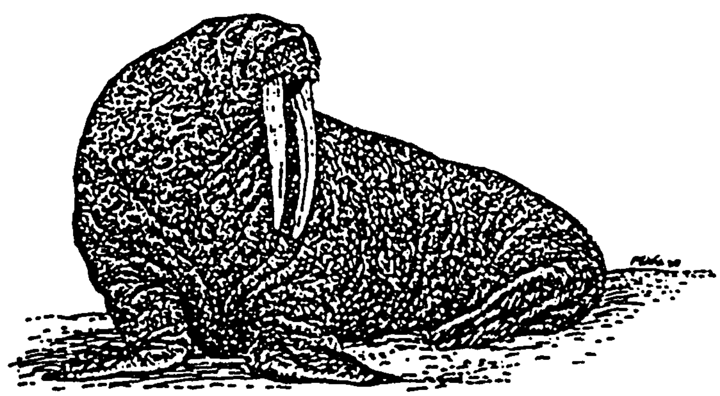
C. REPORTING

Each transient name was abbreviated (e.g., MIW for minke whale, or ISC for ice stress cracking), and all of the SUPPORTING and TRANSIENT DATA are identified by an abbreviation. Those data are on a computer base file and may be retrieved by the abbreviation. Animal species are arranged in phylogenetic sequence. Categories of sound sources (common names of animals or physical mechanisms) may be found by means of the INDEX in section VI of this catalog.

Sound level is expressed as dB *re* 1 µPa, and sound source levels are referenced to 1 m. Target strength measurements are given in dB *re* 1 μN^2. Durations (secs) of averaged and peak-hold data and analyzing filter bandwidths appear with the analyses.

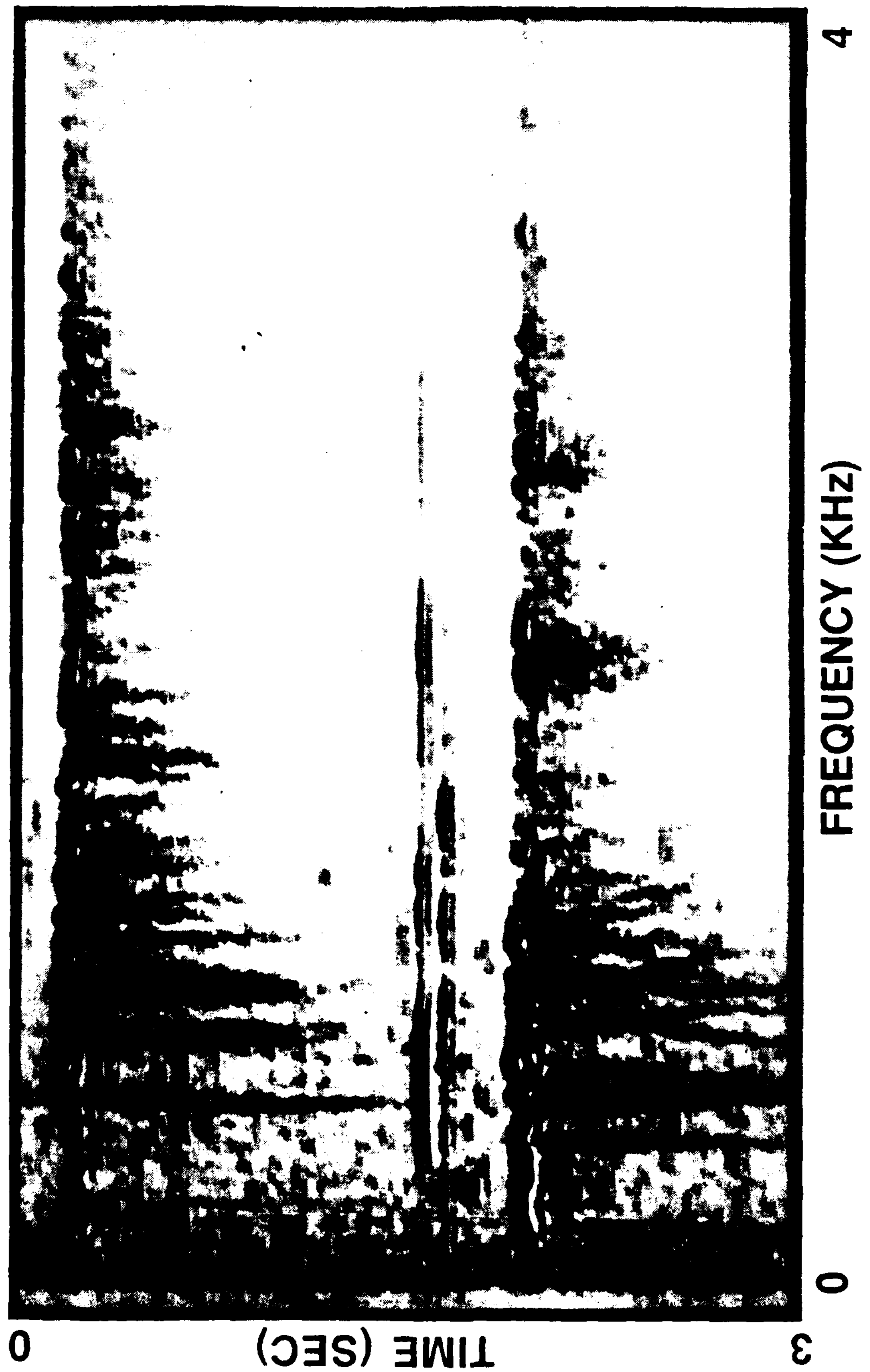
III. CATALOG

A. BIOLOGICAL TRANSIENTS

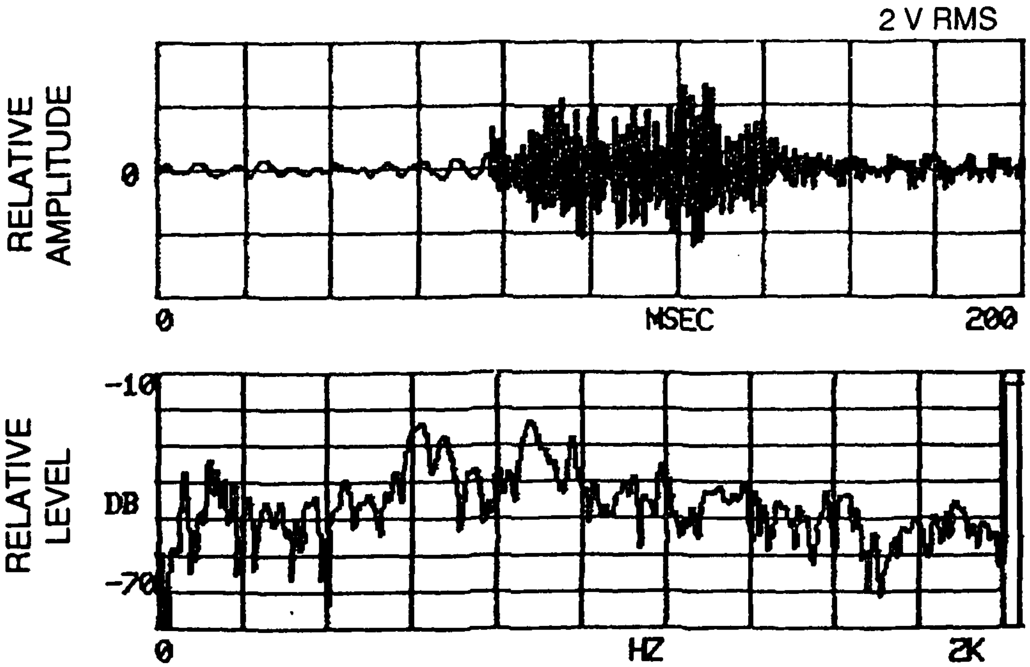
SOURCE	***WAL Walrus, Odobenus rosmarus***
DISTRIBUTION	Circumpolar, fairly close to land and island masses. Not in central Arctic. All other areas, possibly excepting N Greenland, E Beaufort. Females and most males migrate among ice floes near pack ice: N, summer, S, winter.
NUMBERS	Generally unknown, probably 50-100 thousand.
LIFE HISTORY	Males grow to 3.5 m (1350 kgm); females to 3 m (800 kgm). Appearance: very heavy whiskers, tusks on both sexes; skin rough and wrinkled, blubber nearly 8-cm thick; contains some brown hair, but mostly naked, hind limbs bend forward as with sea lions. Color: light brown or tan. Large pouches near throat can be inflated for buoyancy and resonance of sound during sexual activity. Pupping: April-May, with nursing to 1 year. Longevity: to 30 yrs. Food: molluscs, worms, sea urchins, Arctic cod, occasionally other marine mammals, e.g., ringed and bearded seals, narwhals. Dive: to 80 m. Predators: man, killer whales, polar bears. 
TRANSIENT OCCURRENCE	Rasp pulses to 300/sec. Increased sounds during aggressive or sexual encounters.

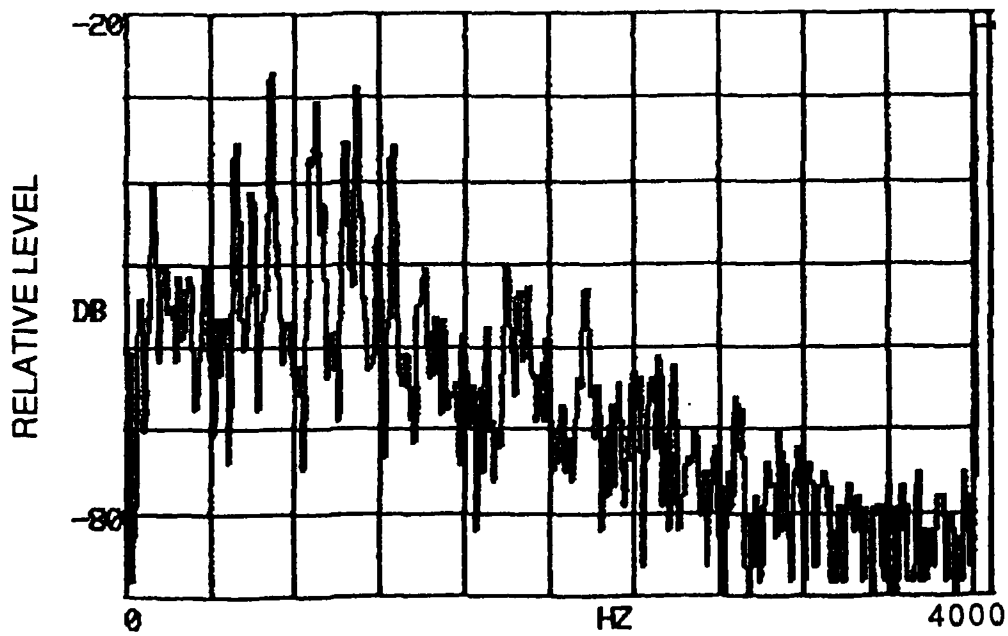
TRANSIENT DATA

SUBJECT	**Walrus: rasps, bell claps, clicks, roars**
DATE	Unknown
LOCATION	Alaska coastal and insular areas, and in captivity at an oceanarium
CONDITIONS	Sounds produced as animals moved about near the surface.
TRANSIENT DESCRIPTION	The bell-like sounds are incredible resemblances. The sound is believed to be made with the aid of pharyngeal pouches, which serve to resonate the pressure wave. The pouches are not well developed in females, and it is thought that bell-like sounds are associated with males. They may be produced in vollies of 2-10 repetitions with each sound lasting 1-1.5 sec. Bell sounds may be associated with sexual behavior, and consequently would be most likely encountered April-May. Fundamental frequencies range from 400-1200 Hz. Rasps have 4-10 pulses with the major energy at 400-600 Hz. The bandwidth of clicks is about 0.4-10 kHz. Since walruses do not venture far out to sea, the presence of their sounds would indicate that the land mass is not far away. Large, loud choruses of walrus sounds may be heard near very large herds.
DATA SOURCE	C. Ray, W.A. Watkins, A. Beal, T.C. Poulter (deceased)
SERIAL	WAL

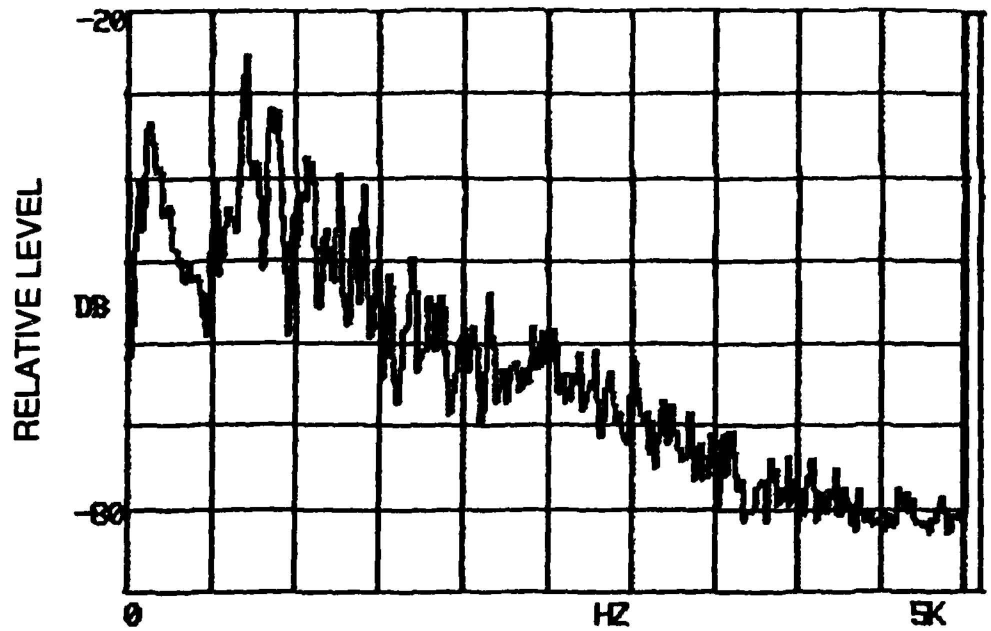


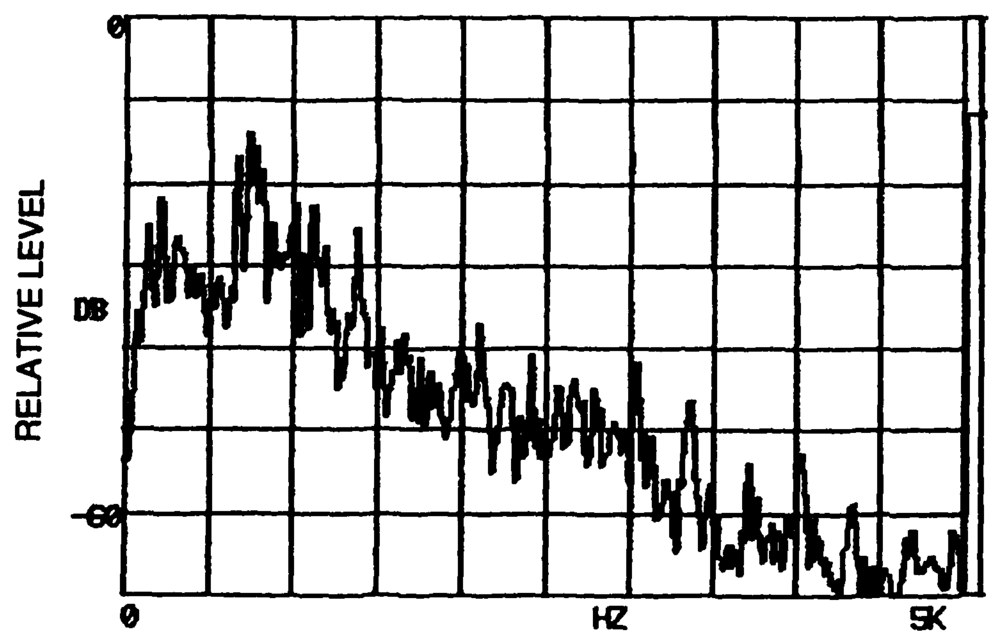
WALRUS, BELL-CLUCKS-BELL (AFB-15 Hz)



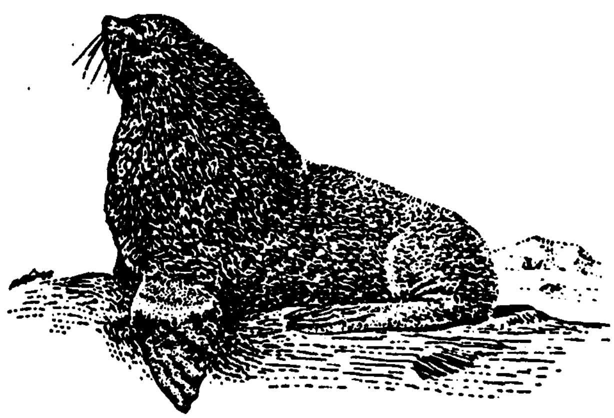


Walrus, waveform and spectrum of short bell (above), spectrum of long bell (below). AFB 7.5 Hz (above) 15 Hz (below)



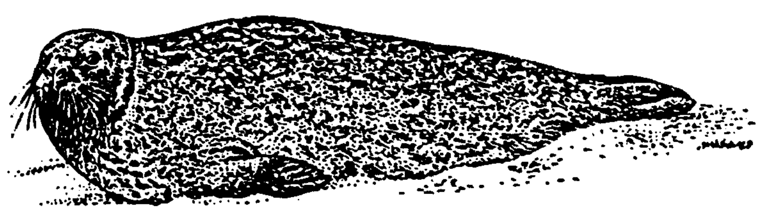


Walrus, spectrum of 2 long bells (0.96 sec. average, above), peak hold spectrum of 4 long bell sounds (6 sec., below).
AFB 18.75 Hz

SOURCE	***SSL Steller Sea Lion, Eumatopias jubata***
DISTRIBUTION	Bering Sea as far N as Bering Strait (some records, to Herschell I., E Beaufort), Okhotsk, Sakhalin, Kamchatka region. Move S in winter, N in summer. Center of distribution in Aleutians. Only found in N Pacific.
NUMBERS	Often found in large breeding colonies. 200 thousand in Aleutians, perhaps 300 thousand, total.
LIFE HISTORY	Males grow to 3.1 m (2,240 lbs), females to 2.5 m (600 lbs). Color: variable yellowish brown, males with large dark scruffy necks, i.e., manes, pups light-dark brown, occasional albinos. Pupping: May-June, annually/female. All animals remain fairly close to shore. Longevity: 17-20 yrs. Scrappy behavior, even killer whales seldom attack them. Cautious, difficult to capture and hold in captivity, will threaten boats and men at sea. 
TRANSIENT OCCURRENCE	Extremely vociferous, variable in occurrence, wide range of durations. Most sounds are socially induced.

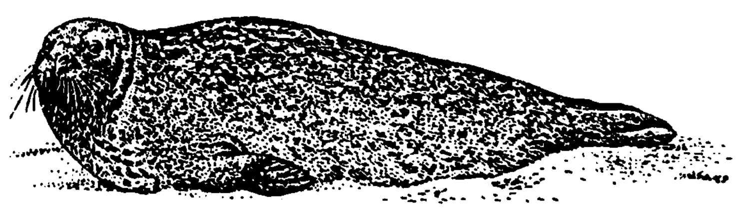
TRANSIENT DATA

SUBJECT	**Steller or Northern Sea Lion: snorts, growls, bleats, barks, clicks**
DATE	Unknown
LOCATION	Unknown
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	The sounds were described qualitatively as harsh, high intensity, and very much like those of California sea lions. This species is very vociferous. Vocalizations occur between pups and mothers, harem bulls and cows, and bulls confronting one another. Bulls roar and hiss at one another. Several vocalizations are produced underwater. As with the California sea lion, even with head exposed, airborne sounds couple well with the water. Time and frequency domain characteristics are not described, nor are source levels available.
DATA SOURCE	Recordings unavailable
SERIAL	SSL

SOURCE	***HAS Harbor or Common Seal, Phoca vitulina***
DISTRIBUTION	Atlantic: Icelandic coasts, Finmark, Baltic, off Stockholm, S Greenland, Baffin and Hudson bays down to Maine, including G. St. Lawrence. Pacific: Chukchi, Bering, Okhotsk seas, Pribilof and Aleutian islands, SE Alaska, W Canada, overlaps spotted.
NUMBERS	Unknown, but possibly 500 thousand.
LIFE HISTORY	Harbor seals confused with spotted seals. Sometimes regarded as one species, P. vitulina. Size: Males 1.5-1.8 m (250 lbs), females, 1.2-1.5 m (200 lbs). Color: varied, usually light gray with black spots of varied separation and shape, undersides are lighter. Pupping: One born on land February-September, takes to water before weaning, unlike spotted seals. At birth, pups have shed white coat. Longevity: to 30 yrs. Food: fish (e.g., cod, whiting, flounders, salmon, turbot), shellfish, squid. Only found close to shore, at sandy islands, or the ice edge. Move from heavy ice in fall and winter. In water, seals are solitary, but when hauled out they form large groups to thousands. Dive: to 200 m. Visual acuity: same as land mammals. Hearing: in water about as acute as humans in air, but they respond to frequencies to180 kHz, in air about 15 dB down as compared to water. 
TRANSIENT OCCURRENCE	Not well known, but click trains, grunts, and growls are produced sporadically.

TRANSIENT DATA

SUBJECT	**Harbor or Common Seal: clicks and growls**
DATE	Unknown
LOCATION	Unknown
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	Clicks are 8-16 kHz. Pups considered to be more vocal than parents.
DATA SOURCE	Recordings unavailable
SER!AL	**HAS**

SOURCE	***SPS Spotted Seal, Phoca largha***
DISTRIBUTION	W Beaufort, Chukchi, N Bering, Okhotsk seas, Commander I., Kamchatka, N Alaska Peninsula. Confined to the Pacific.
NUMBERS	Unknown, perhaps 500 thousand.
LIFE HISTORY	Size: same as harbor seals with which this species is often confused. Appearance: large headed, short bodied, and limbed. Life history similar to that of harbor seals, but spotted seals birth on ice (Feb.-April), and young born with long white coats not shed for up to 3 weeks when they enter water. Males mature at 3-6 yrs, females at 2-5 yrs. Unlike otariids (eared seals) spotted seals are monogomous, beginning about 10 days before pupping. They mate for the young of the next year about 1 month after pupping. Pups do not swim until after weaning, then at speeds to 3.8 m/sec. Longevity: to at least 30 yrs. Move offshore to pack ice in fall and winter as the nearshore waters freeze. Remain on pack ice until spring breakup. Food: fish, crustaceans, and cephalopods. 
TRANSIENT OCCURRENCE	Sounds unknown.

TRANSIENT DATA

SUBJECT	**Spotted Seal: clicks**
DATE	Unknown
LOCATION	Unknown
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	Click trains are produced that are very similar to those of the harbor or common seal--low-level impulses that center at about 12 kHz. Source levels, occurrence patterns, other sounds, methods or reasons for sound production are unknown. Since this seal is common where found, additional bioacoustics work is called for.
DATA SOURCE	Recordings unavailable
SERIAL	**SPS**

SUPPORTING DATA

SOURCE

RIS Ringed Seal, Phoca hispida

DISTRIBUTION

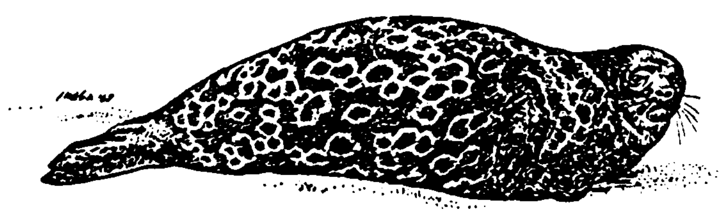
Circumpolar, most widely distributed and northern marine mammal. N Pacific-Arctic Ocean, pole, down to Korea, Japan. N Atlantic-Arctic Ocean, pole to Baltic Sea and Labrador.

NUMBERS

Unknown, but probably in millions. The most numerous marine mammal.

LIFE HISTORY

Size to: 1.5 m. Color: usually light gray background, spotted with gray rings, giving the common name. Maintains lairs (dens) in snow on ice for protection from polar bears, man, cold, and for giving birth and nurturing young. Will start holes in fall new ice or in refrozen polynyas, keeping them open by scratching with claws, a behavior revealed by characteristic sounds. Food: large crustacean plankton, bottom crustacea, fish. Predators: man, polar bear, walrus, killer whale. This species is much sought after by native populations for its value as food and clothing items.

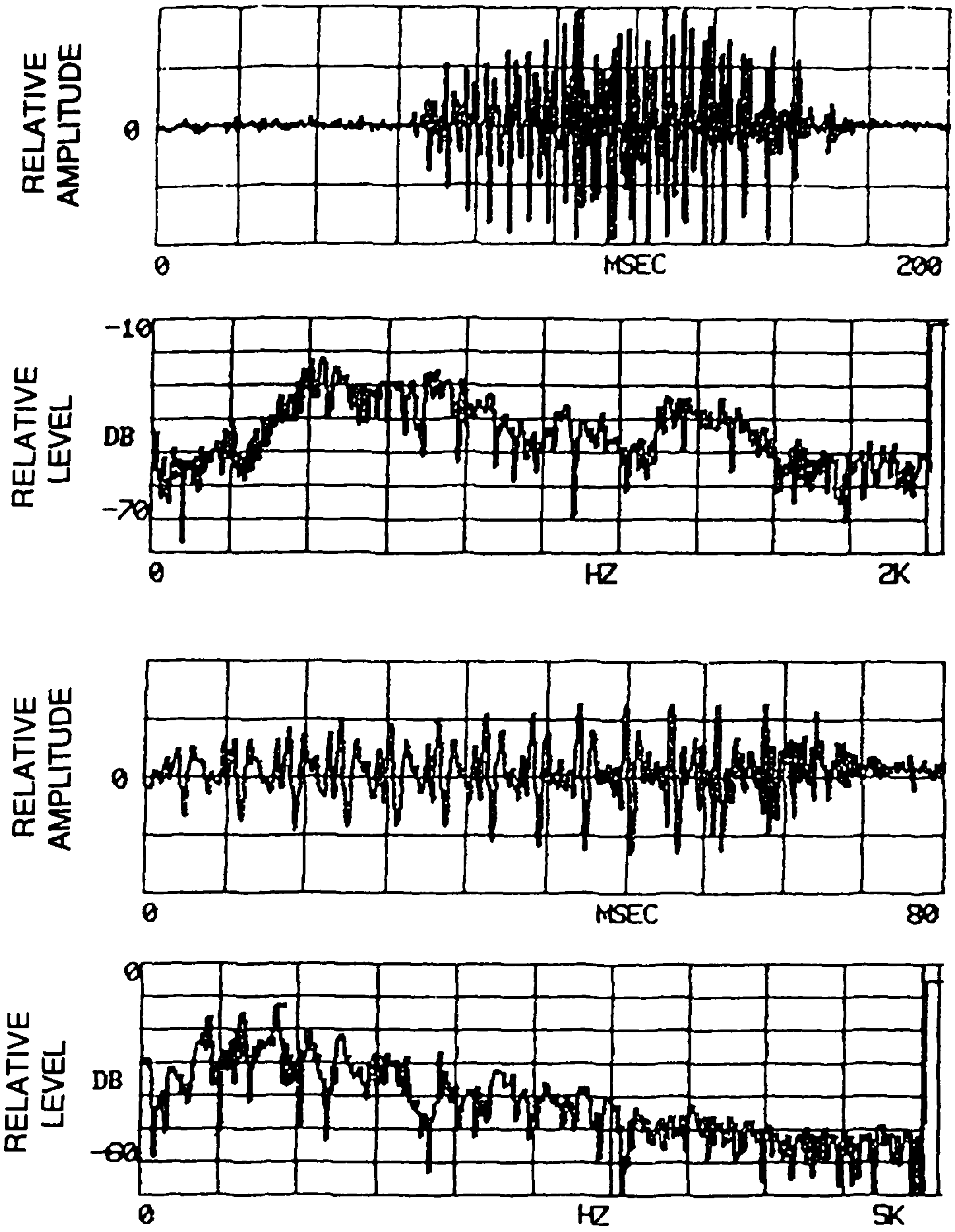


TRANSIENT OCCURRENCE

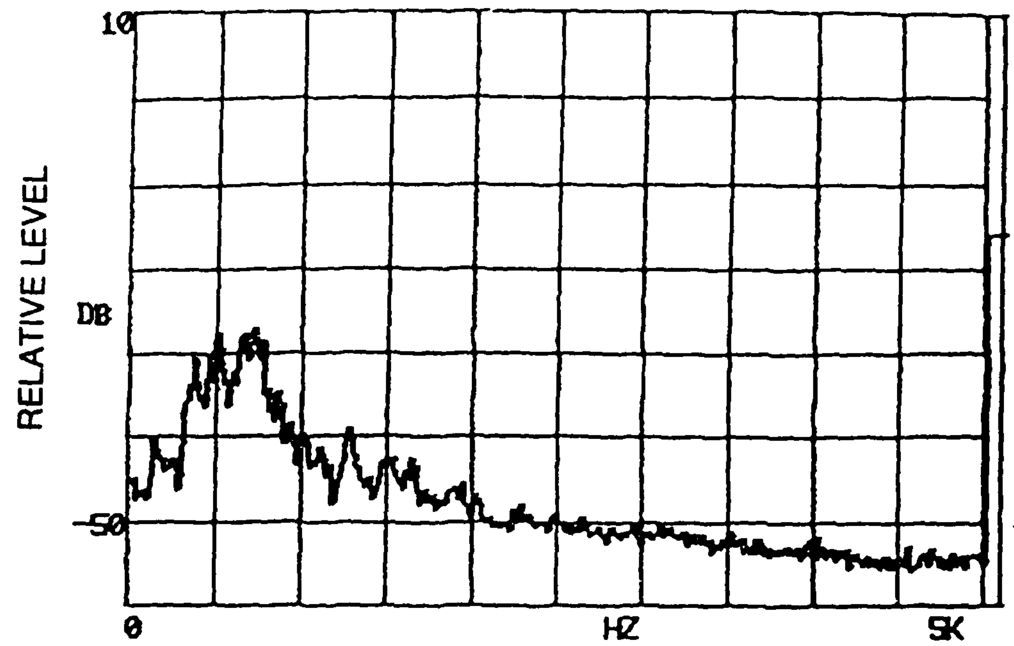
Infrequent, increases with breeding. Diurnal occurrence. Vocally responds to man-made pulses.

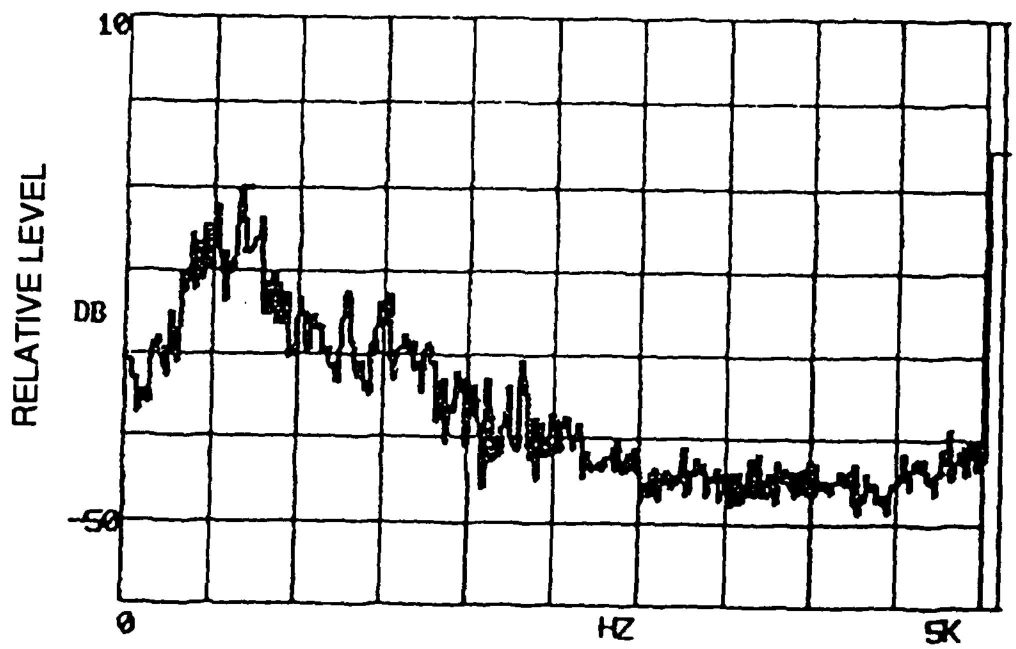
TRANSIENT DATA

SUBJECT	**Ringed Seal: scratch, rub-like, squeak, bark-like sounds**
DATE	March-April 1984
LOCATION	Kotzebue Sound, Chukchi Sea, Alaska; Canadian Arctic
CONDITIONS	Most sounds recorded under ridged and hummocked 2-m, landfast ice, 14.5-m water (K. Sound). Others recorded under 1-m sea ice, in deep water near International Date Line (Chuckchi).
TRANSIENT DESCRIPTION	Scratch sounds, produced by claws during ice hole maintenance, have peak energy at 1-6 kHz. Their duration was 40-500 ms/scratch, and source levels varied from 98 to 102 dB. This seal's vocalizations (rub-like, squeak, bark sounds) have peak energy at varied locations of the spectrum from 0.5-9 kHz, and a variable duration of 80 ms-1.5 s. Vocalization source levels were 91 to 131 dB. They peaked in occurrence at 1930 hrs, and were negatively correlated with windspeed and ambient temperature. By using an array, it was determined that most seal sounds originated from active ice regions offering easier access to their lairs above and better protection from predators. The frequency of occurrence or type of sound production was not correlated with the presence of man-made industrial noise, but squeaks and bark-like sounds sounds virtually always followed the appearance of low-frequency (fundamental, 106 Hz) pulse trains of unknown origin.
DATA SOURCE	W.C. Cummings, D.V. Holliday, I. Stirling
SERIAL	RIS

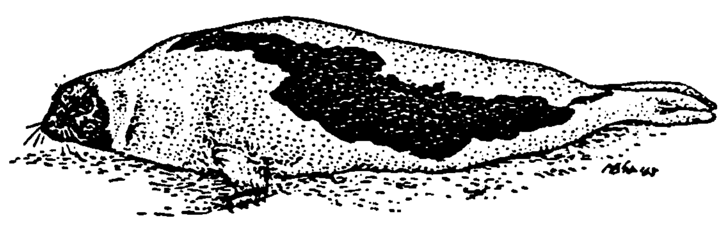


Ringed seal, waveform and spectrum of a single quacking bark (above), same with different time scale (lower).
AFB 7.5 Hz (upper) 18.75 (below)



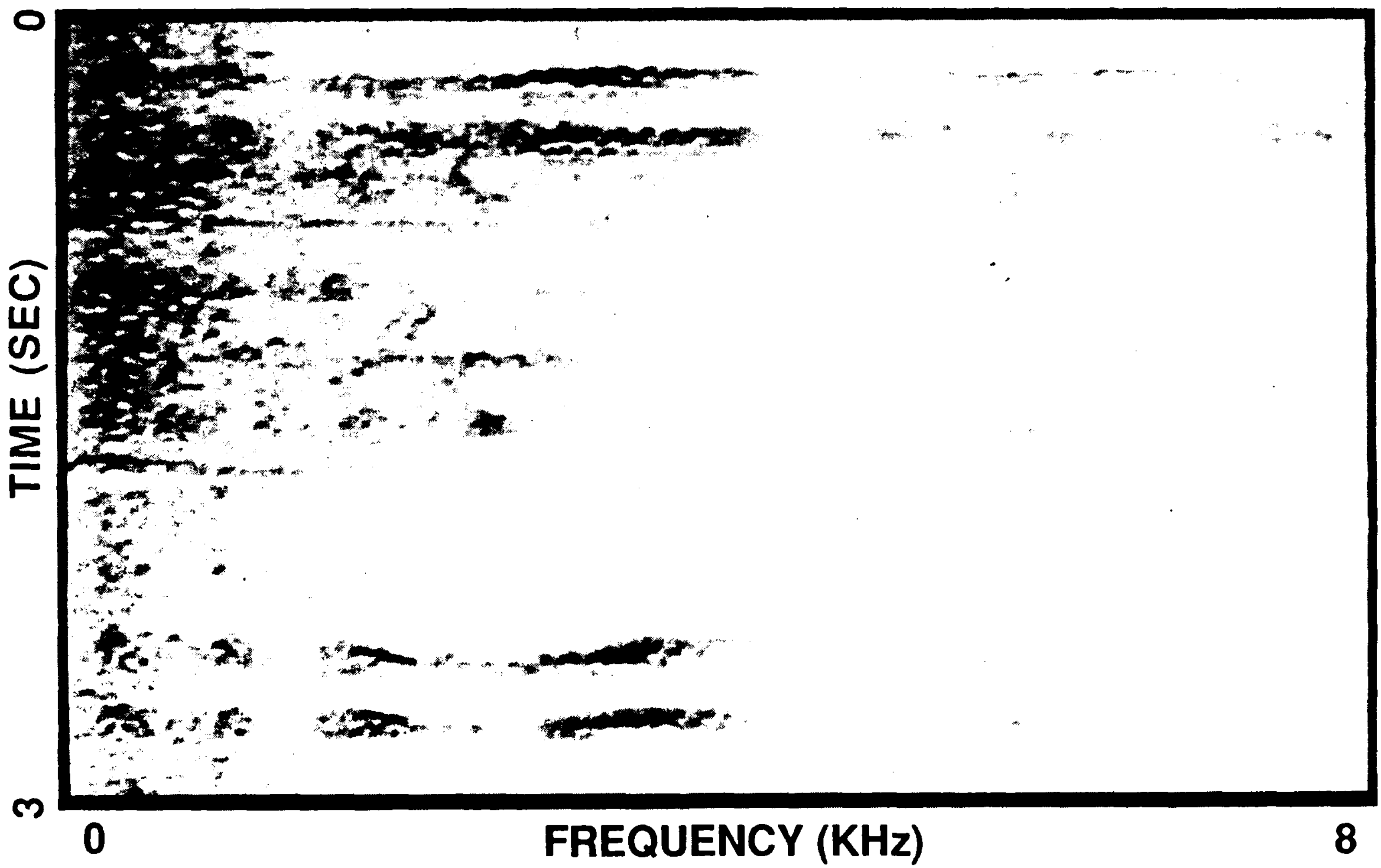


Ringed seal, peak hold spectrum for 8 consecutive quacking barks (3.09 sec., above), exponential average of same (below). AFB 18.75

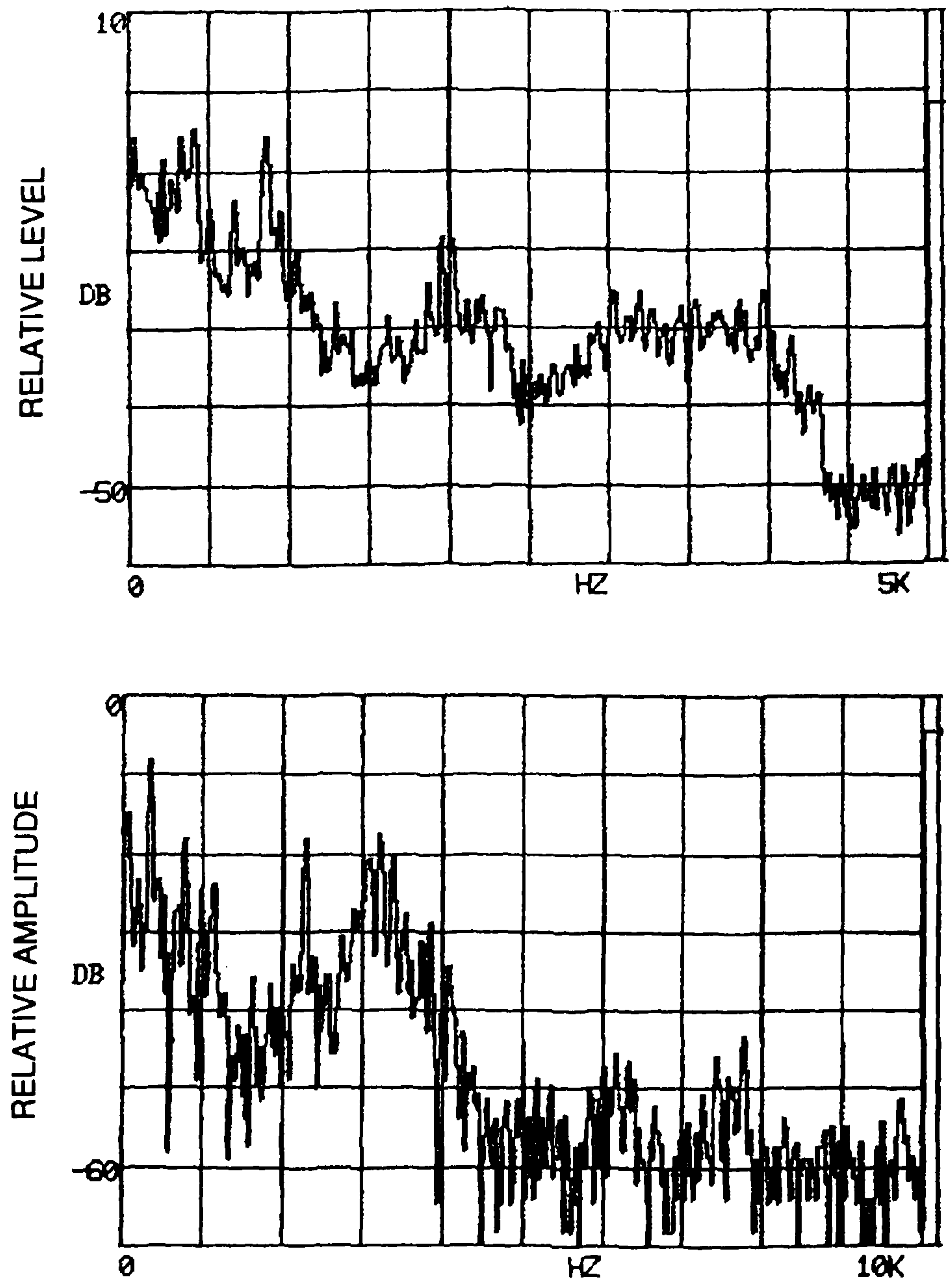
SOURCE	***HPS Harp Seal, Pagophilus groenlandicus***
DISTRIBUTION	Only in Arctic Atlantic to 83 deg N. From Cape Chaelyuskin, Franz Josef Land, Spitsbergen, N Greenland, Baffin Bay, Davis Strait, Labrador Sea to just S of Newfoundland. S to only N coast of Norway. Kara and White seas.
NUMBERS	Unknown, possibly 2-2.5 million.
LIFE HISTORY	Major populations in White Sea, Greenland Sea, N of Jan Mayen; and Gulf of St. Lawrence and ice fields off E Newfoundland. Size: males to 1.8 m (300 lb), females same (260 lb). Color: pups, 2-3 days old, covered with thick white "wool" followed by a soft gray spotted coat prized for pelts, adults mostly whitish gray with wide blackish banding. Move N in summer, for heavy feeding, and S in winter where they breed in spring. Migration as much as 2500 nm in precise directions. Keep open access holes through ice. As many as 40 animals use a single hole. Pupping: late February-early March; breeding in ice fields. Food: small planktonic crustacea or fish, such as capelin, cod, haddock, herring. Dive: well adapted for deep submerge (to 200 m), long duration. Longevity: to 34 yrs. 
TRANSIENT OCCURRENCE	Click trains, repetition to about 130/s, vocalizations mostly confined to spring breeding and whelping season.

TRANSIENT DATA

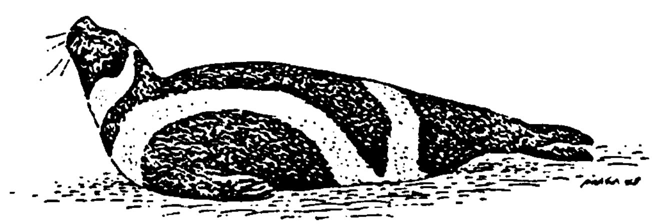
SUBJECT	**Harp Seal: tones, trills, warbles, grunts, clicks, dove coo, knocking, gull and blackbird-like**
DATE	4 March 1967
LOCATION	Bay of St. Lawrence, Canada
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	In all, 15 categories of sound production have been identified with the harp seal. Harmonic structure of click sounds occurs above the fundamental of about 2 kHz. The sounds are produced mostly during the whelping and breeding season (spring). Pups produce wailing sounds. Few, if any, outstanding sounds are made at other times of the year.
DATA SOURCE	B. Mohl, K. Ronald, J. Terhune, C. Ray, W. Watkins
SERIAL	**HPS**



HARP SEAL, QUACKS, 3 PAIRS (AFB-30 Hz)

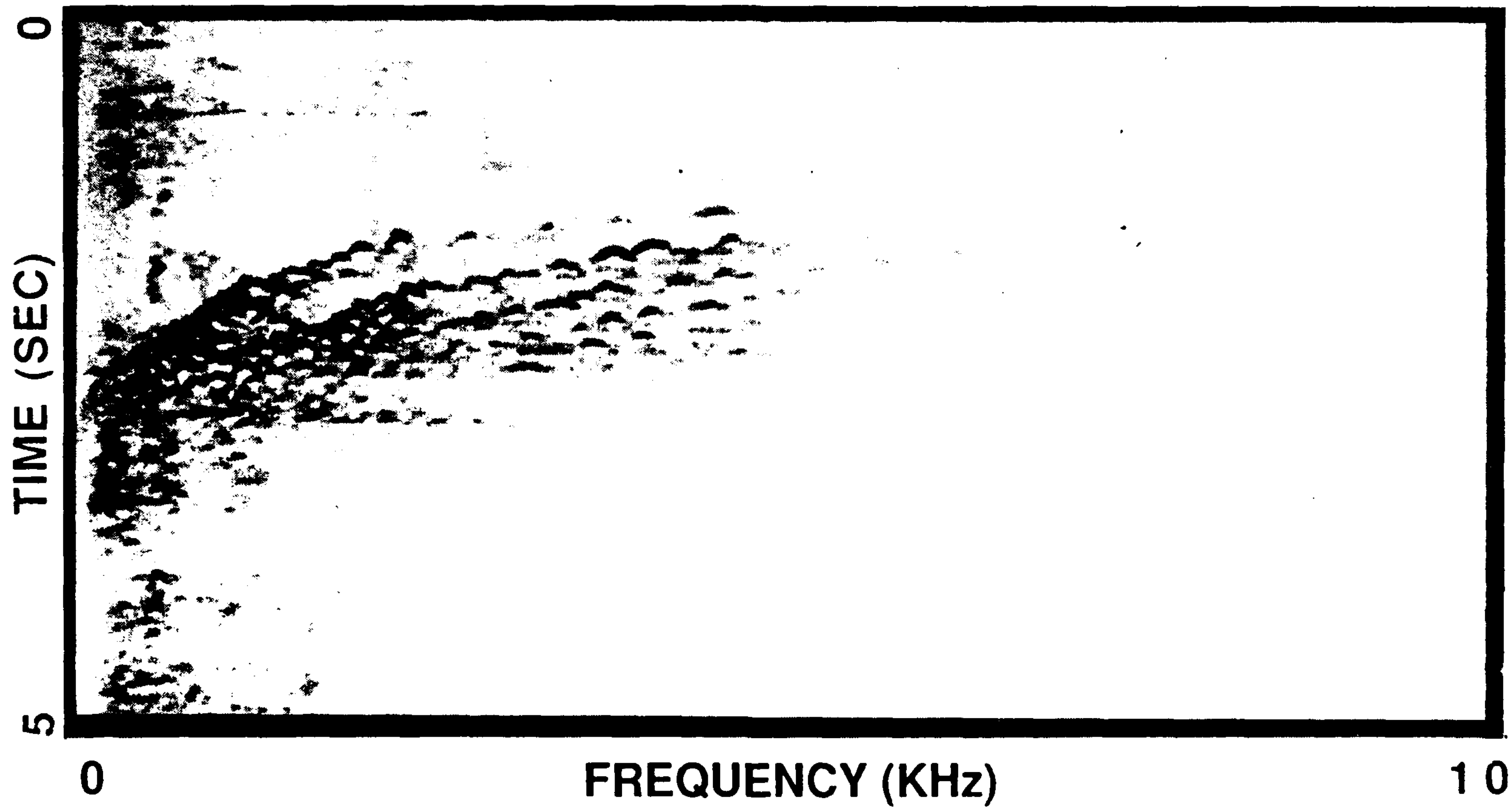


Harp seal, peak hold spectrum of 4 quacks (10 sec., above), spectrum of 1 quack (below). AFB 18.75 Hz (above) 37.5 Hz (below)

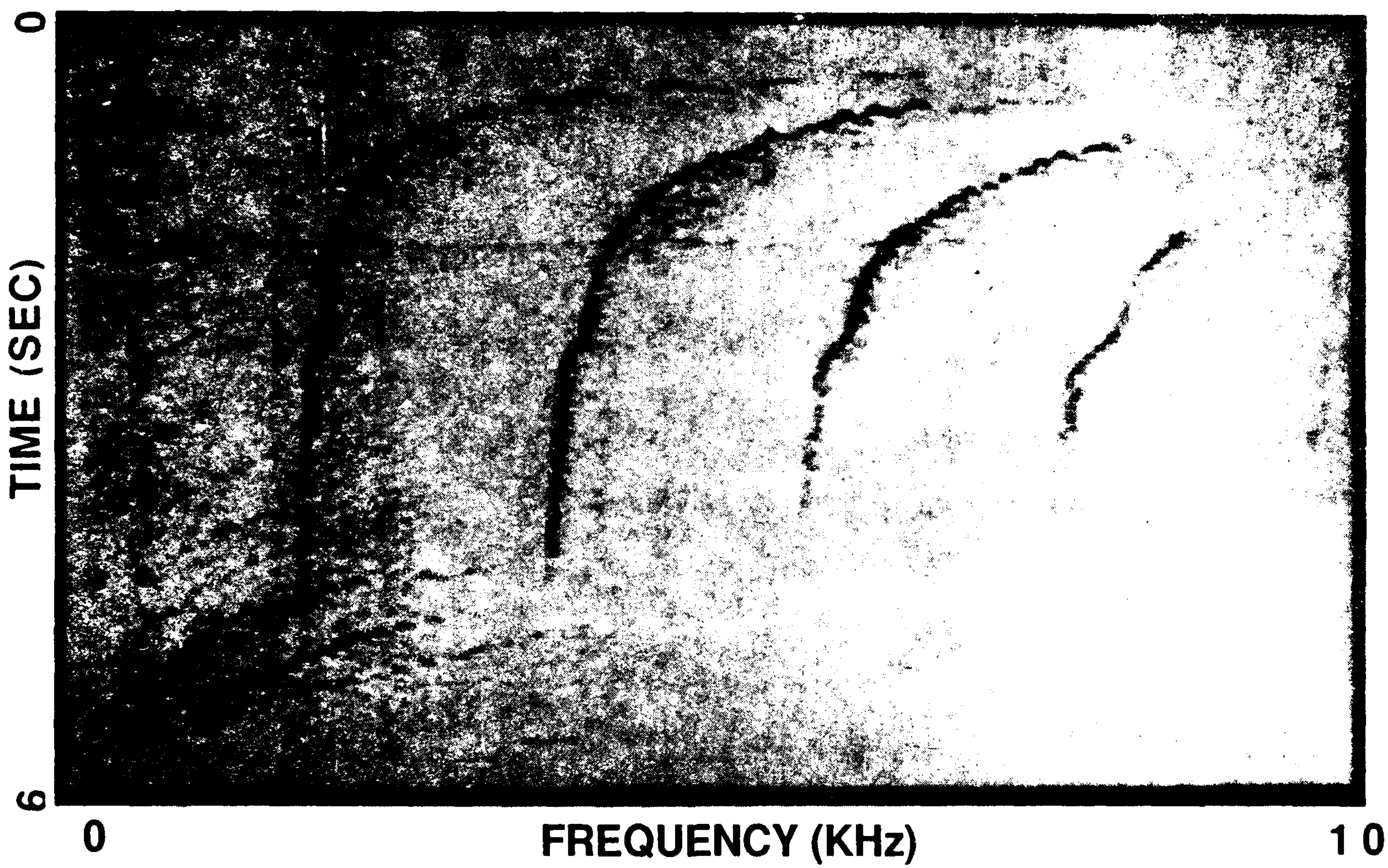
SOURCE	***RBS Ribbon Seal, Histriophoca fasciata***
DISTRIBUTION	Occasionally as far N as Pt Barrow, but mostly W Bering and Okhotsk seas from about St Lawrence to Kurile islands, including Commander Island, Kamchatka, Sakhalin, Tatar Strait. Moves N-S with changes in heavy ice cover.
NUMBERS	Unknown, probably 200-250 thousand.
LIFE HISTORY	Not found near land masses. During late winter and spring, they haul out on moderately thick "clean" ice. Rest or sleep for long periods without looking for enemies, often far from the water's edge. In winter, found near the southern edge of the ice. Size: males and females to about 1.7 m (200 lbs). Breeding is polygamous. Visual acuity: eyesight in air poor, reason why they are approached easily. When aroused, they move as fast as a man running. Pupping on ice, April-first part of May. Nursing over 3-4 weeks when the fat little pups take to water. Mothers flee, rather than defend their pups. Color: males dark brown or almost black with light ribbons (bands) around the tail region and each flipper; females lighter with indistinct bands. Food: fish, shellfish, squid. Tend to be solitary animals. 
TRANSIENT OCCURRENCE	Varied, depending upon behavior.

TRANSIENT DATA

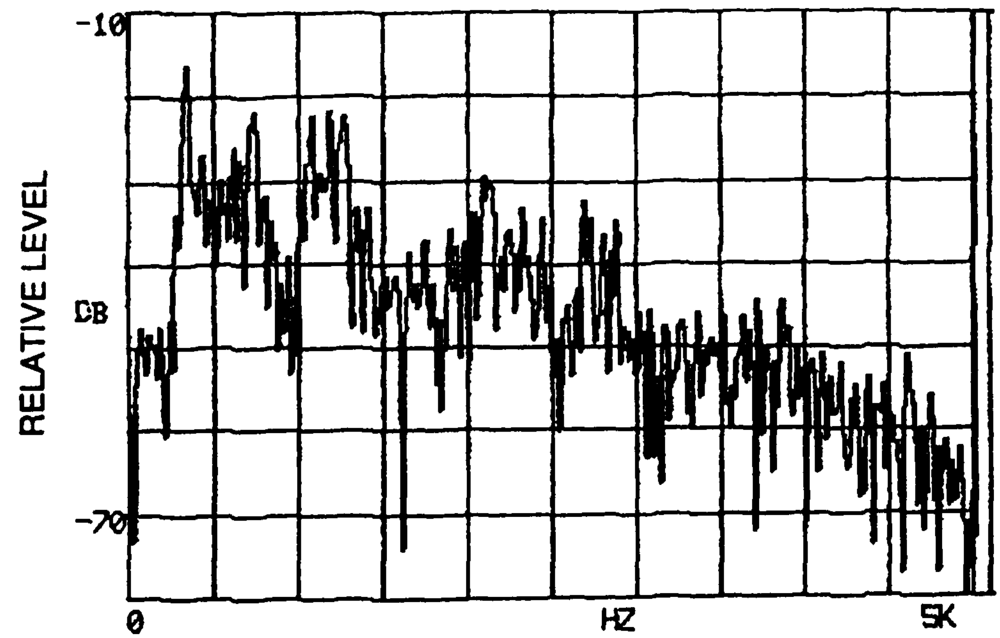
SUBJECT	**Ribbon Seal: downsweeps and puffing sounds**
DATE	16-18, 23 May 1967
LOCATION	Off Savoonga, St. Lawrence, Island
CONDITIONS	Spring ice floes, stretches of open water
TRANSIENT DESCRIPTION	Downsweeps are divided into 3 categories, depending upon duration. Short sweeps (1 sec, or less) sweep downwards from 2000-1750 to 300 Hz. Medium sweeps (1.3-1.8 sec) sweep from 5300-2000 to 100 Hz. Long sweeps (4-4.7 sec) sweep from 7100-3500 to 2000 Hz. Up to 6 harmonics are seen in the spectrum. Source level was not measured directly, but was assumed to be 160-165 dB. Puffing sounds are broadband (< 5 kHz) with a duration of a little less than 1 sec. These sounds were typically 20-25 dB less than sweeps. Sound production and other behavior does not seem to be affected by moderate disturbance from boats and people.
DATA SOURCE	C. Ray, W.A. Watkins
SERIAL	RBS

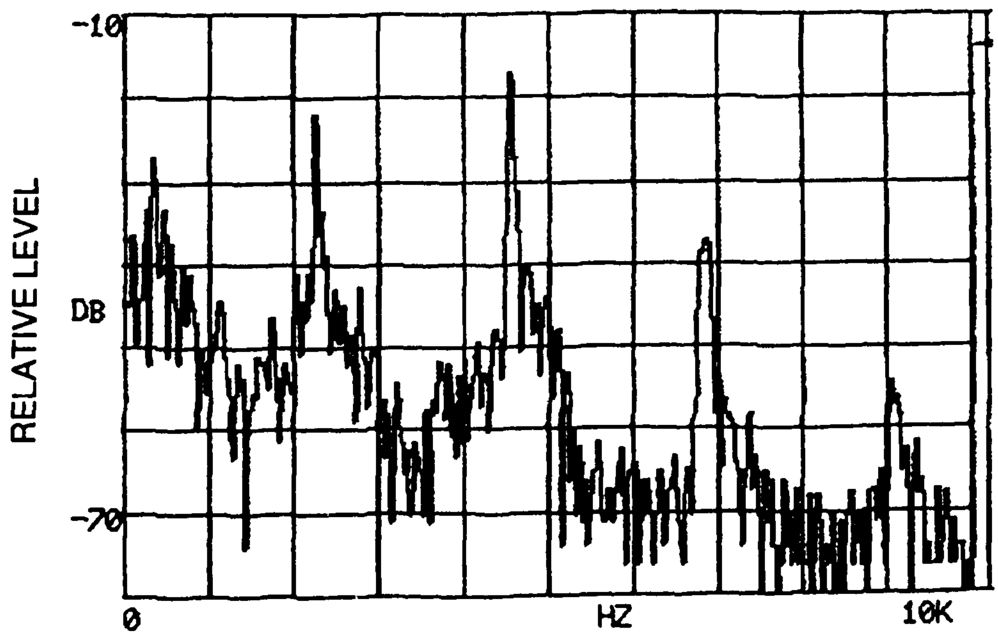


RIBBON SEAL, DOWNSWEEP ROAR (AFB-37.5 Hz)

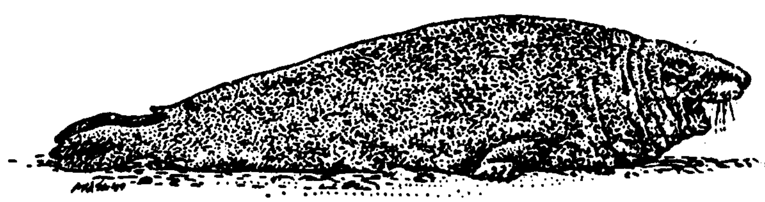


RIBBON SEAL, DOWNSWEEP SCREAM (AFB-37.5 Hz)



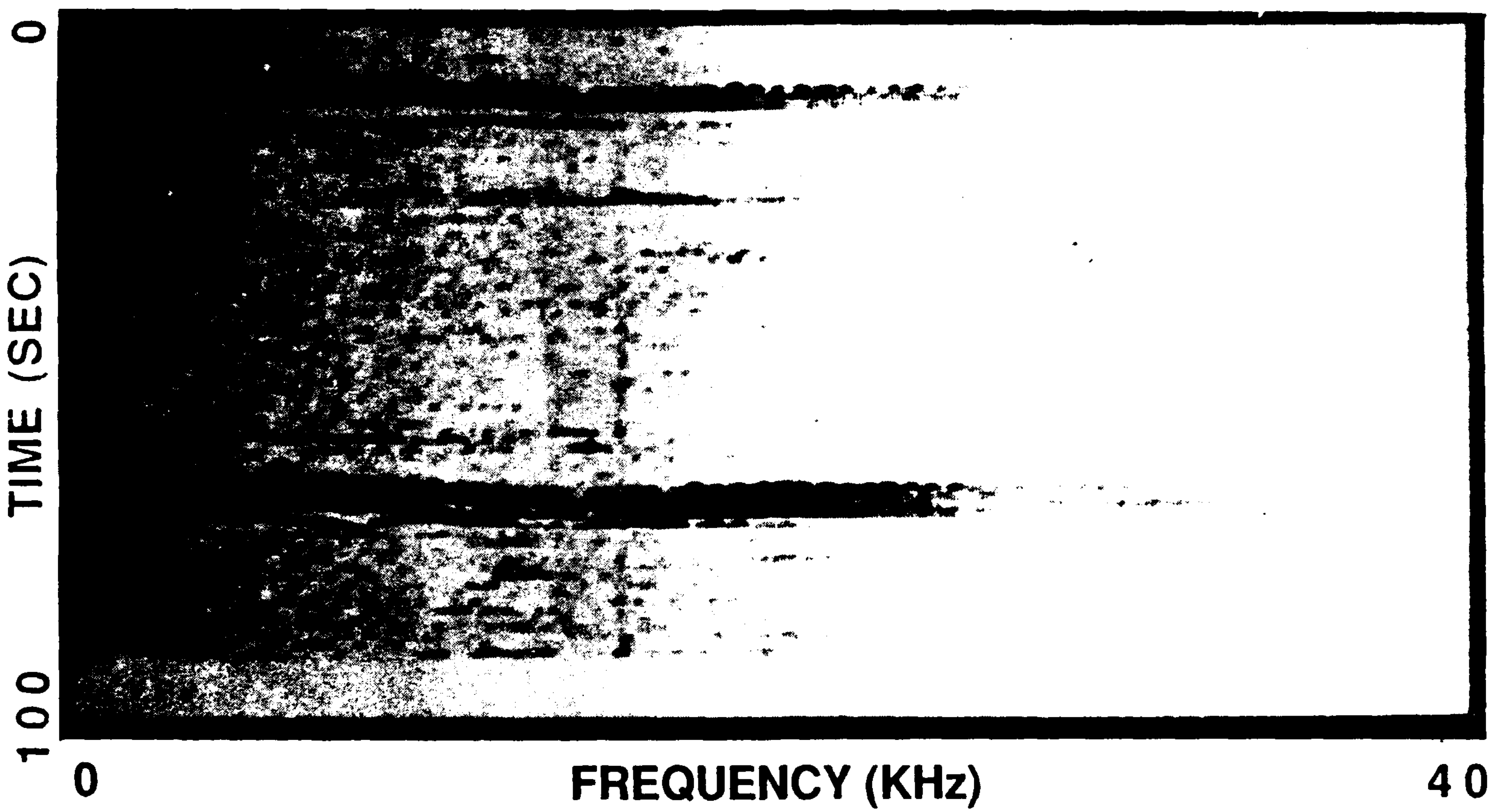


Ribbon seal, spectrum of broadband roar (above), same of downswept scream (below). AFB 18.75 Hz (above) 37.5 Hz (below)

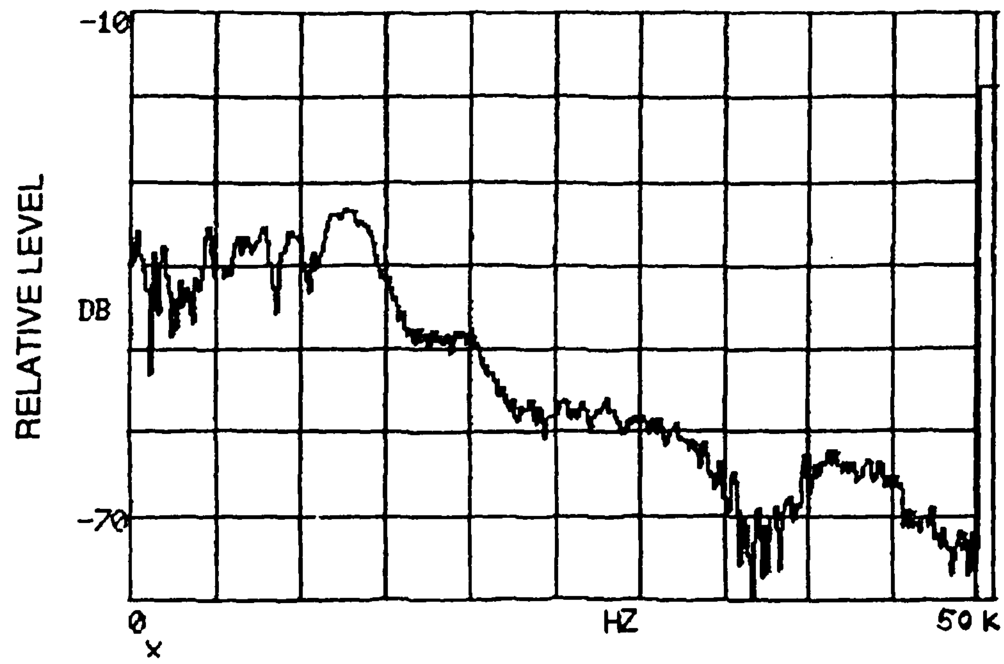
SOURCE	***GRS Gray Seal, Halichoerus grypus***
DISTRIBUTION	N Atlantic: MA to N Newfoundland, English Channel to Iceland and Murmansk; Baltic, White, Norwegian, Barents seas. Unverified off S Greenland. Not in Pacific or central Arctic.
NUMBERS	Unknown, probably more than 50 thousand.
LIFE HISTORY	Size: males grow to 3 m (600 lbs). Color: dark and light gray, brown and silver; darker dorsally, lighter ventrally, spotting is common. Pupping: in February-March in Baltic and St. Lawrence regions, September-December elsewhere. Spend first two years of life at sea. Longevity: to 40 yrs. Food: pelagic, midwater, bottom fishes; crustaceans, molluscs. Predators: man, polar bear, killer whale. 
TRANSIENT OCCURRENCE	Trains of clicks. Sporadic vocalizations.

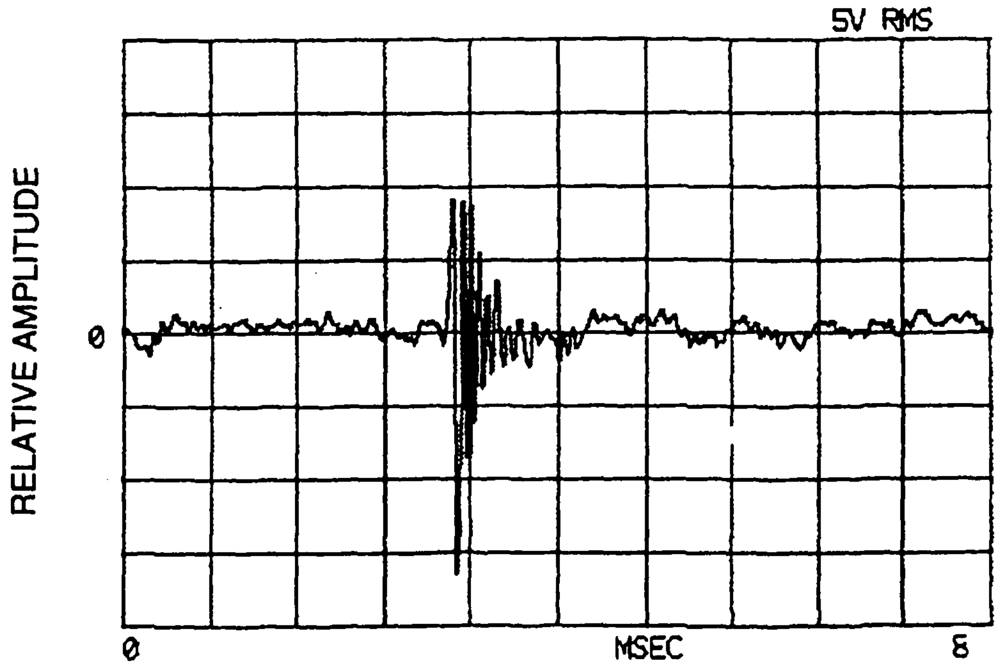
TRANSIENT DATA

SUBJECT	**Gray Seal: clicks, bleats**
DATE	1975-1978
LOCATION	In captivity, Pt. Loma (San Diego, CA)
CONDITIONS	Held in small enclosures of filtered sea water and in pens.
TRANSIENT DESCRIPTION	Clicks to 40 kHz appear in trains. They also are produced as doublets, 0.1-0.2 sec apart, with the pairs occurring at random intervals. Repetition rate in trains are up to 60/sec. Pups recognize calls of mothers and will respond vocally with bleating calls. Clicks originally thought to be used in active sonar, a notion later proven incorrect by Ridgeway's experiments.
DATA SOURCE	W.C. Cummings, S.H. Ridgway, C. Ray
SERIAL	GRS

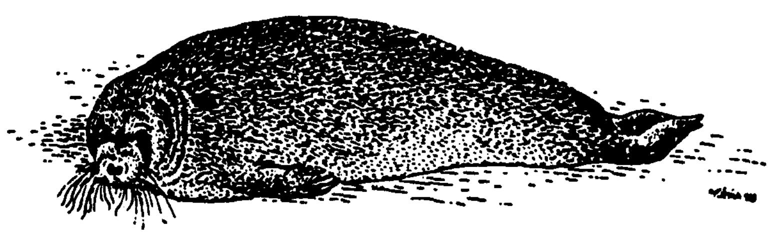


GRAY SEAL, 2 CLICK TRAINS (AFB-150 Hz)



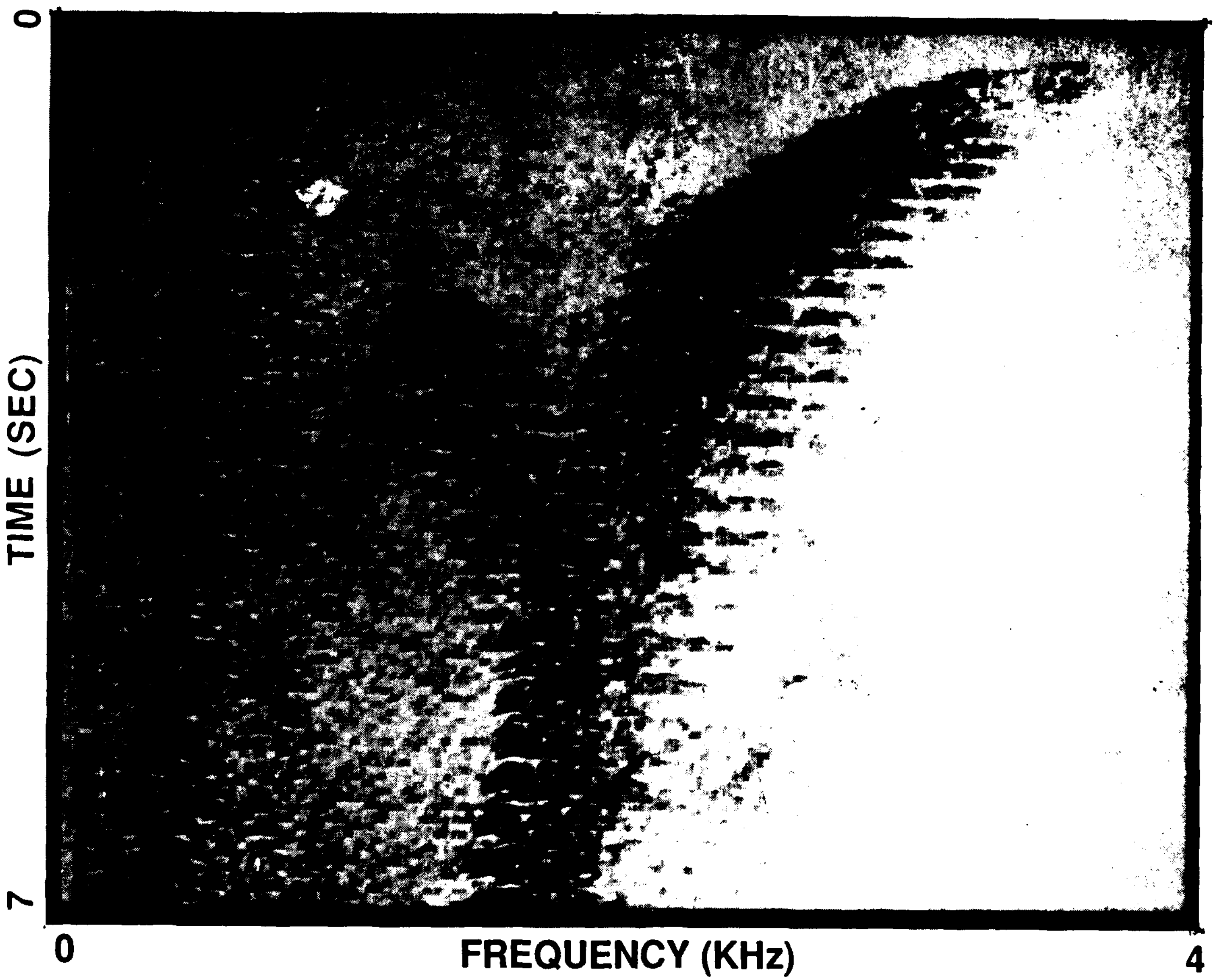


Gray seal, spectrum of short click train (above), waveform of single click (below). AFB 187.5 Hz

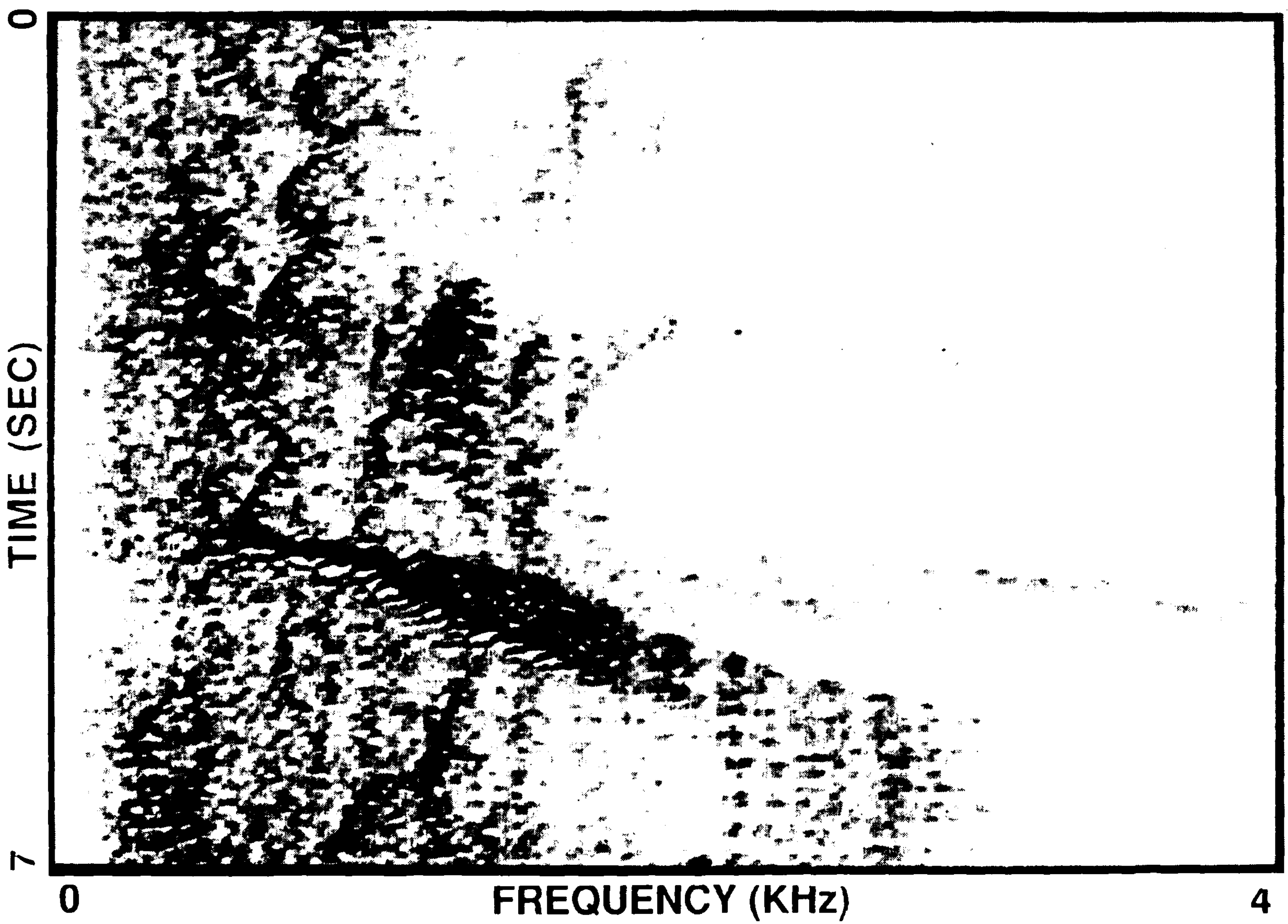
SOURCE	***BES Bearded Seal, Erignathus barbatus***
DISTRIBUTION	Circumpolar, to 80-85 deg N. S to Okhotsk, Tatar Strait, Sakhalin, Hokkaido, Hudson Bay, Gulf of St. Lawrence. Some near Scotland and Normandy. Need to be near naturally open water revealed by their sounds. Second most Arctic (to ringed).
NUMBERS	As many as 150-200 thousand. Not in very large groups like some other Arctic pinnipeds. Small groups seen on ice and beaches.
LIFE HISTORY	Size: to 2.3 m (600 lbs). Color: grayish, brown or red on head, dark brown down middle of back. Appearance: heavy growth of whiskers, hence "bearded", heavy looking animal. Pupping: on unprotected ice floes, April-May, with sexually mature females giving birth every other year. Food: shellfish, octopus, and bottom fishes, e.g., Arctic cod, sculpin, flounder. Predators: Arctic fox, walrus, polar bear, man. Unlike ringed seals, these animals generally do not keep access or breathing holes open in the ice; when heard, they signify open water, even if limited to a wide crack. Known to use ringed seal holes. 
TRANSIENT OCCURRENCE	Trills (to over 1 min) in spring. Occurrence peaks at about 0200, 0400 hrs. To 7 calls/min, no difference with helo noise.

TRANSIENT DATA

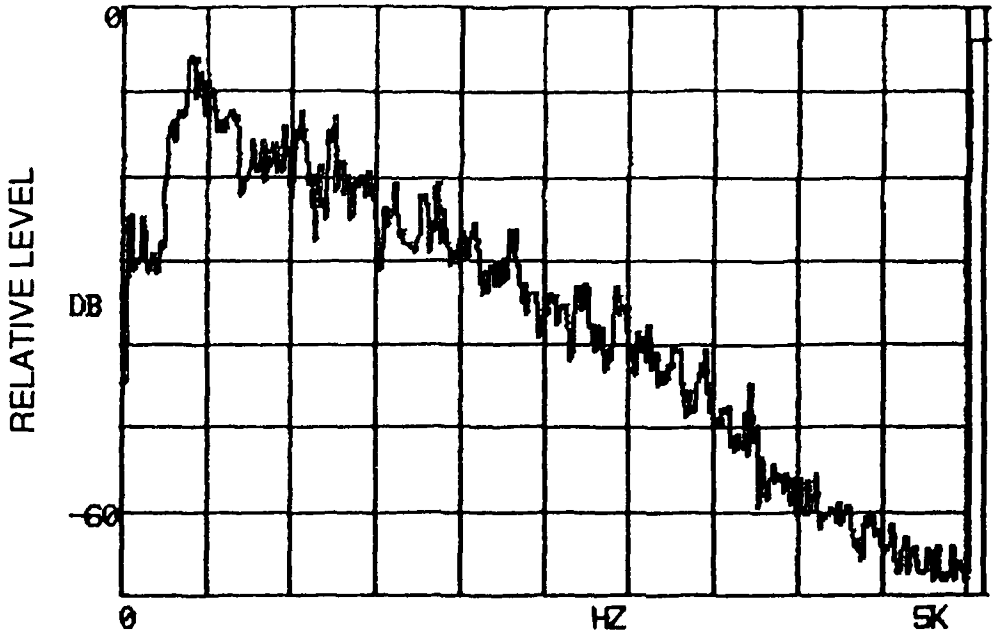
SUBJECT	**Bearded Seal: trills, whistles, bangs, chirps, yelps**
DATE	May-June 1980, April-May 1982, March-April 1983
LOCATION	Off Pt. Barrow, Prudhoe Bay, Chukchi Sea
CONDITIONS	Heavy ice cover with some natural lead or other openings varying to wide open leads. Typical springtime conditions. Winds 0-35 kn
TRANSIENT DESCRIPTION	During the spring months of March-June, trills of bearded seals are perhaps the most common MIZ sound from marine mammals. They may be encountered at these times around the polar MIZ regions less than 85 deg. N. Trills are usually descending undulating (in frequency and amplitude) signals that begin as high as 4-5 kHz, ending up with most energy at about 200 Hz. Although not as common, trills may go upwards as well. Echolocating clicks to 120 kHz have been recorded from this species at source levels of 160-180 dB. Single clicks may have up to 25 kHz bandwidth. Whistles may extend up to 10 kHz. Yelps last 50-180 ms with fundamental frequencies of 1.3-2.5 kHz. Bangs are broadband impulse noises.
DATA SOURCE	W.C. Cummings, W.A. Watkins, J. Ford, W. Mowbray, H. Winn, C. Ray, J. Burns
SERIAL	**BES**

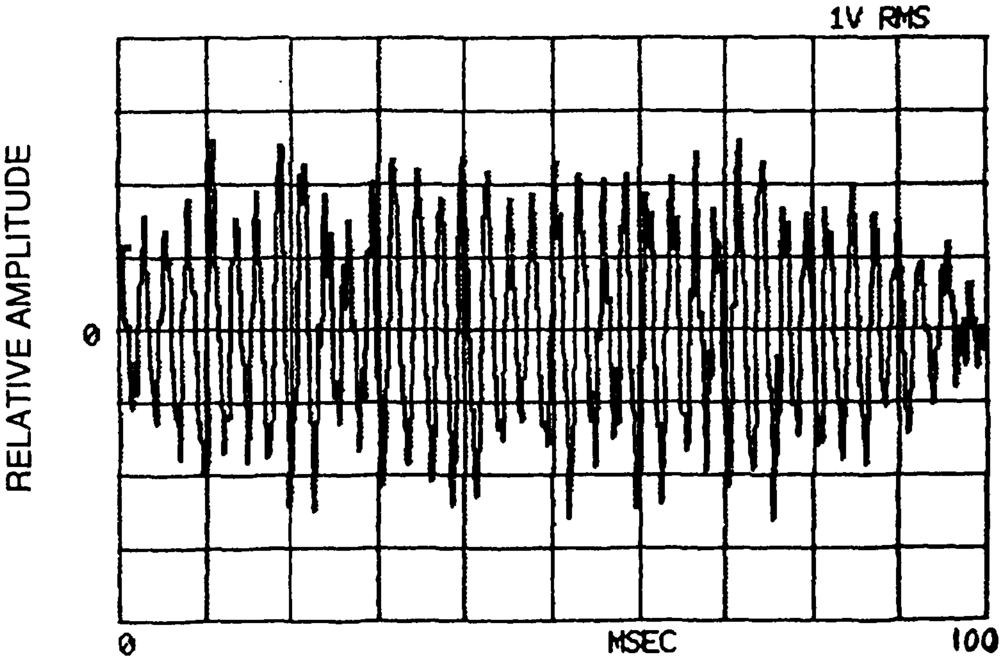


BEARDED SEAL, TRILLS FROM TWO (AFB-15 Hz)

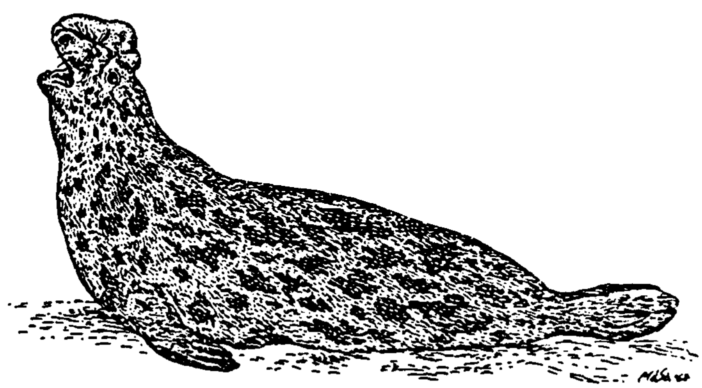


BEARDED SEAL, END-BEGIN TRILLS (AFB-15 Hz)





Bearded seal, spectrum, one-half way through a trill (above), waveform of same (below). AFB 18.75 Hz

SOURCE	***HDS Hooded Seal, Cystophora cristata***
DISTRIBUTION	Only in Arctic Atlantic from Spitsbergen and Bear Island to Iceland, Jan Mayen to just S of Newfoundland, Baffin Bay, Davis and Denmark Straits. Deep water, heavy ice floes.
NUMBERS	Unknown, possibly 0.5-0.75 million.
LIFE HISTORY	Common name comes from the male inflatable nasal sac. Bulls display sac when fighting or in sexual displays. Females courted by several males at once. Mate 2 weeks after giving birth. Copulation in the water. Pupping in March-first part of April on middle of large floes. Pups active quickly after birth, and within a few days take to water. Mothers protect pups vigorously. Most females mature at 3 years of age and whelp at 4. Male hooded seals reach sexual maturity at 4-6 yrs. Size: males to 3 m (900 lbs), females a little smaller. Color: adults gray and covered with darker patches. Mostly occur singly or in small groups, except when breeding or moulting, in heavy ice, far from shore. Dive: to at least 75 m. Food: squid, octopus, fish, shellfish. Predators: man, polar bears. 
TRANSIENT OCCURRENCE	Click trains up to 20/s, or more, grunts, and pulsed sounds produced sporadically.

TRANSIENT DATA

SUBJECT	**Hooded Seal: broad and narrowband clicks**
DATE	March 1962 (tank recordings), March 1968, 1971 (field)
LOCATION	New York Aquarium, Gulf of St. Lawrence
CONDITIONS	Quiet tanks. During field recordings there was little wind and no ice movement.
TRANSIENT DESCRIPTION	The click sounds from a captive 1/2 grown male were of two types. One type is narrowband pulse with most energy centered at 4 or 6 kHz. The other is broadband, at least as low as 0.1 and as high as 16 kHz. Most broadband pulses are below 3 kHz. Except for calls involving the males' bladder (hood), most vocalizations are variations of pulsation. In the field, 3 major types of underwater sounds are noted. A type "a" is phonetically described as a "grunt" with most of the energy at 0.2-0.4 kHz. Type "b" sounds like a snort, and it extends from about 0.1-1 kHz, sometimes with harmonics to 3 kHz. Type "c" is a buzz-like sound reaching as high as 6 kHz. All 3 types have durations between 0.5 and 1 sec. Airborne sounds are produced by both species and could be expected to couple with the water at varying degrees of efficiency-- whether animals are on the ice or swimming. The female may produce a defensive call that lasts 1-5 sec, mostly below 0.5 kHz. Male airborne sounds are produced in association with inflation or deflation of the bladder. The inflation sound is about 150 Hz and 0.25 sec in duration. The deflation sound may be 100-500 Hz and 0.5-1 sec in duration. Bladder associated sounds are of low level.
DATA SOURCE	Recordings unavailable
SERIAL	**HDS**

SUPPORTING DATA

SOURCE

GRW Gray Whale, Eschrichtius robustus

DISTRIBUTION

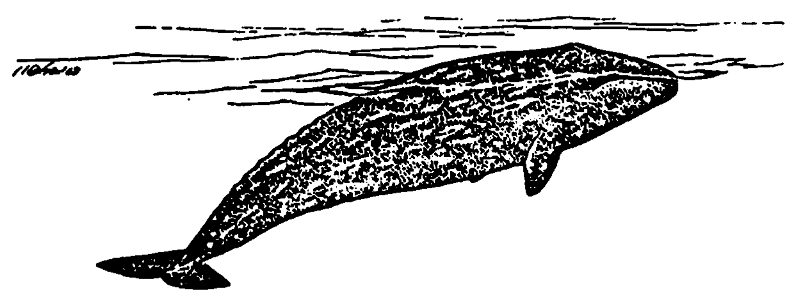
NE Pacific : Bering, Chukchi, Beaufort seas, S to 22 deg N. Remnants from Korea to Okhotsk Sea. Annual migration N-S, to 12000 mi. May be seen among ice floes. N range: June-August (Beaufort), to October (Chukchi). Migrate day and night.

NUMBERS

Once believed to be 100s, probably now to 20 thousand from protection beginning in 1946.

LIFE HISTORY

Size: to 15 m. Color: light gray to light steel blue above midline, lighter below, surface is mottled from whitish patches due to attached, parasitic barnacles. Longevity: more than 40 yrs. Calving: one about every other year, in lagoons or other protected waters in the south, during winter months. Adults feed very little, if at all, for nearly 8-9 mo., while migrating. Food: benthic crustacea, e.g., amphipods, isopods, mysids, euphausiids, crabs, molluscs, worms. Dive: to 50 m, blows 2-10 times at surface, when migrating, followed by upward extension of flukes and a dive of 2-12 min. Usually found in small groups of 2-4 animals while migrating. Makes deep furrows in bottom and clouds of mud while actively feeding (N waters).

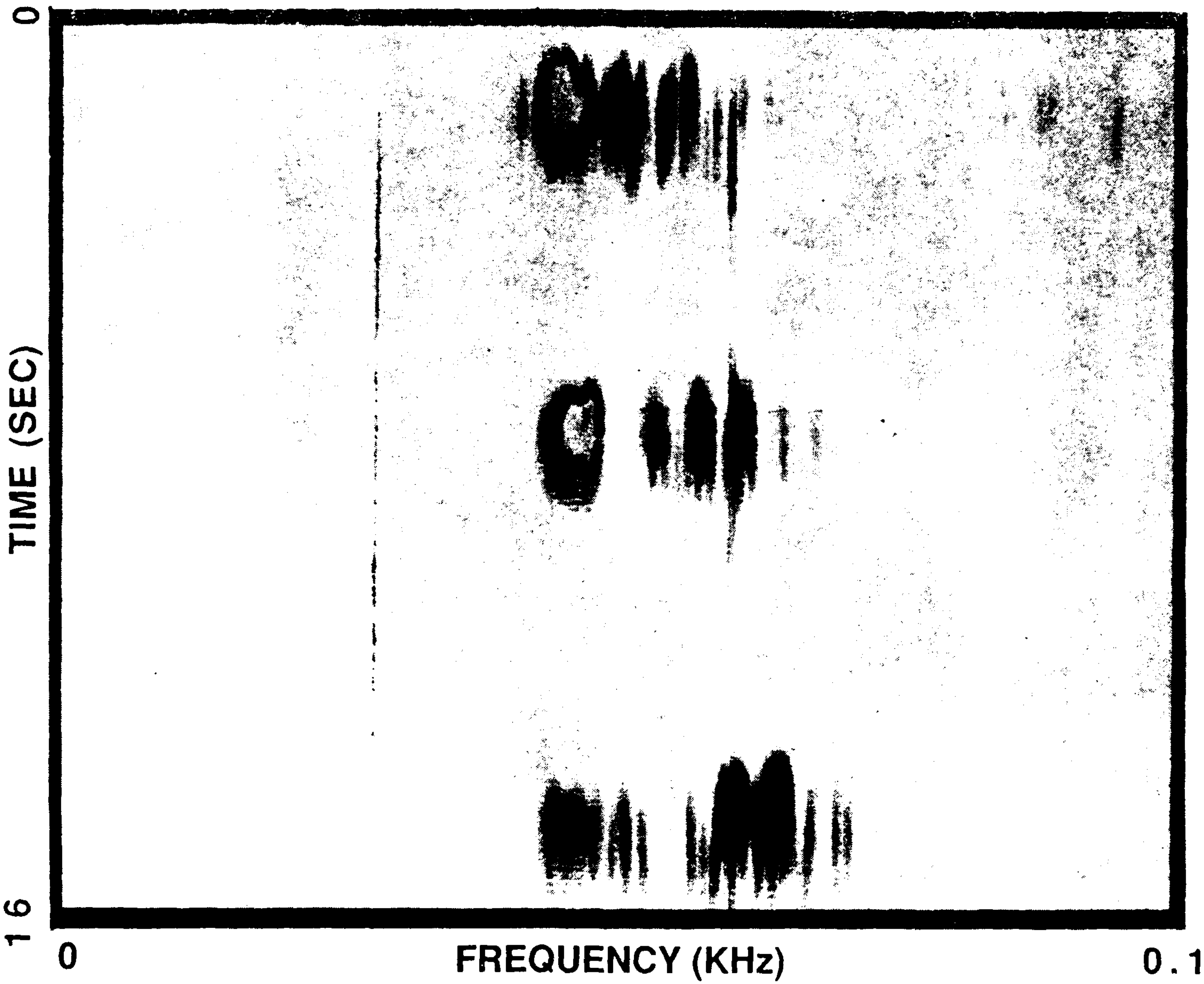


TRANSIENT OCCURRENCE

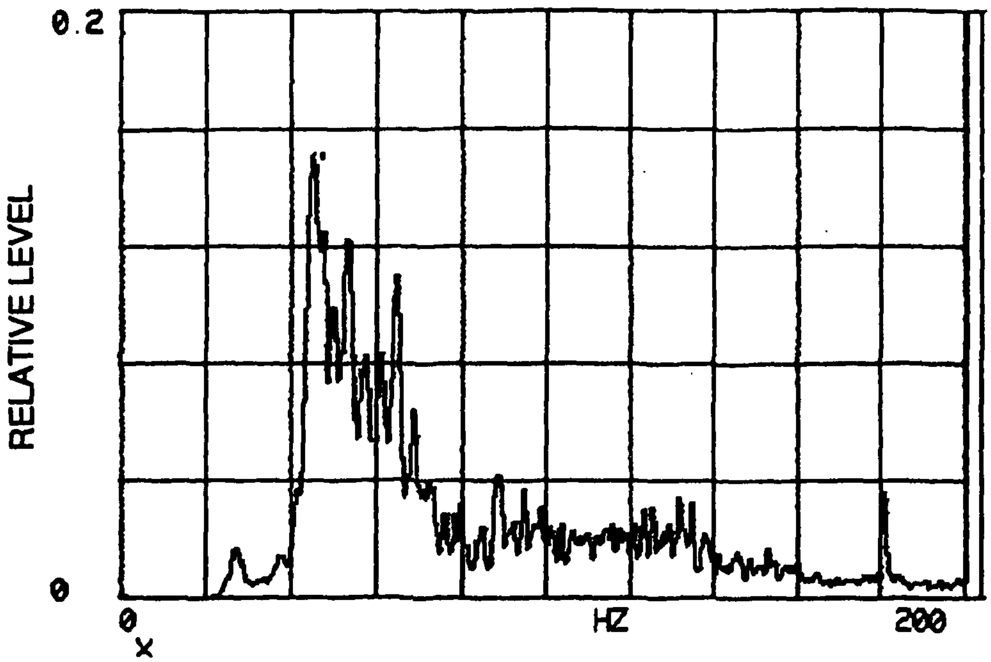
Large variety, but not many sounds. To 53/hr, often, 0. Sounds made day and night. Bubble or click trains, to 25 sounds, 8 sec.

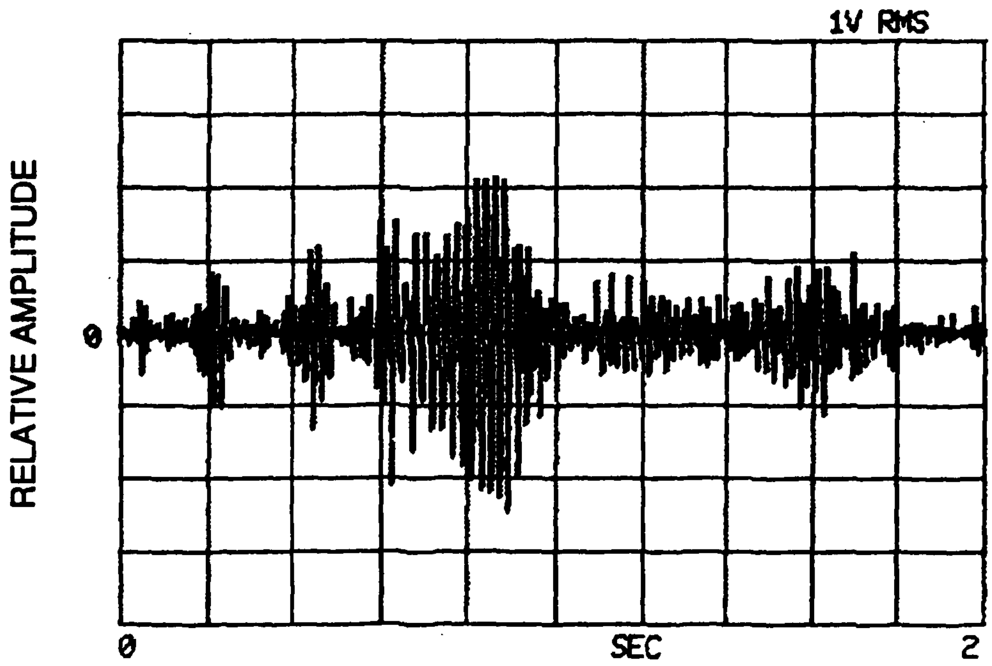
TRANSIENT DATA

SUBJECT	**Gray Whale: moans, knocking sounds, underwater sounds from surface blows**
DATE	Dec-Jan 1966-1968, 1970-1980
LOCATION	Off Pt. Loma (San Diego), CA
CONDITIONS	Variable seas, < 1 m.
TRANSIENT DESCRIPTION	Moans last about 1.5 sec, source levels being about 152 dB, overall. This, their most common sound, may range from 20-200 Hz. Knocks appear in trains of up to 25 elements. Most knock energy is below 500 Hz, but it may reach above 1 kHz. Knock source levels are up to 142 dB. Underwater sounds from surface exhalations are about 1.25 sec long, in the spectrum from 15-175 Hz. While migrating, grays may produce these sounds during day and night. No particular behavior was associated with these sounds. High level, broadband impulses (usually with 2-3 sec of reverberation) accompany breaching. Sounds have been recorded on the main feeding grounds of the Bering and Chukchi seas, but the recordings were unavailable. Two second moaning sounds (5-455 Hz) were recorded in the Beaufort Sea by W.C. Cummings and D.V. Holliday, June, 1980.
DATA SOURCE	W.C. Cummings, P.O. Thompson, M. Dahlheim, W.E. Evans, J. Fish, G. Wenz
SERIAL	GRW

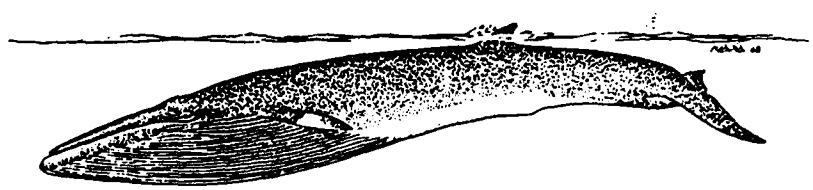


GRAY WHALE MOANS (AFB-0.38 Hz)



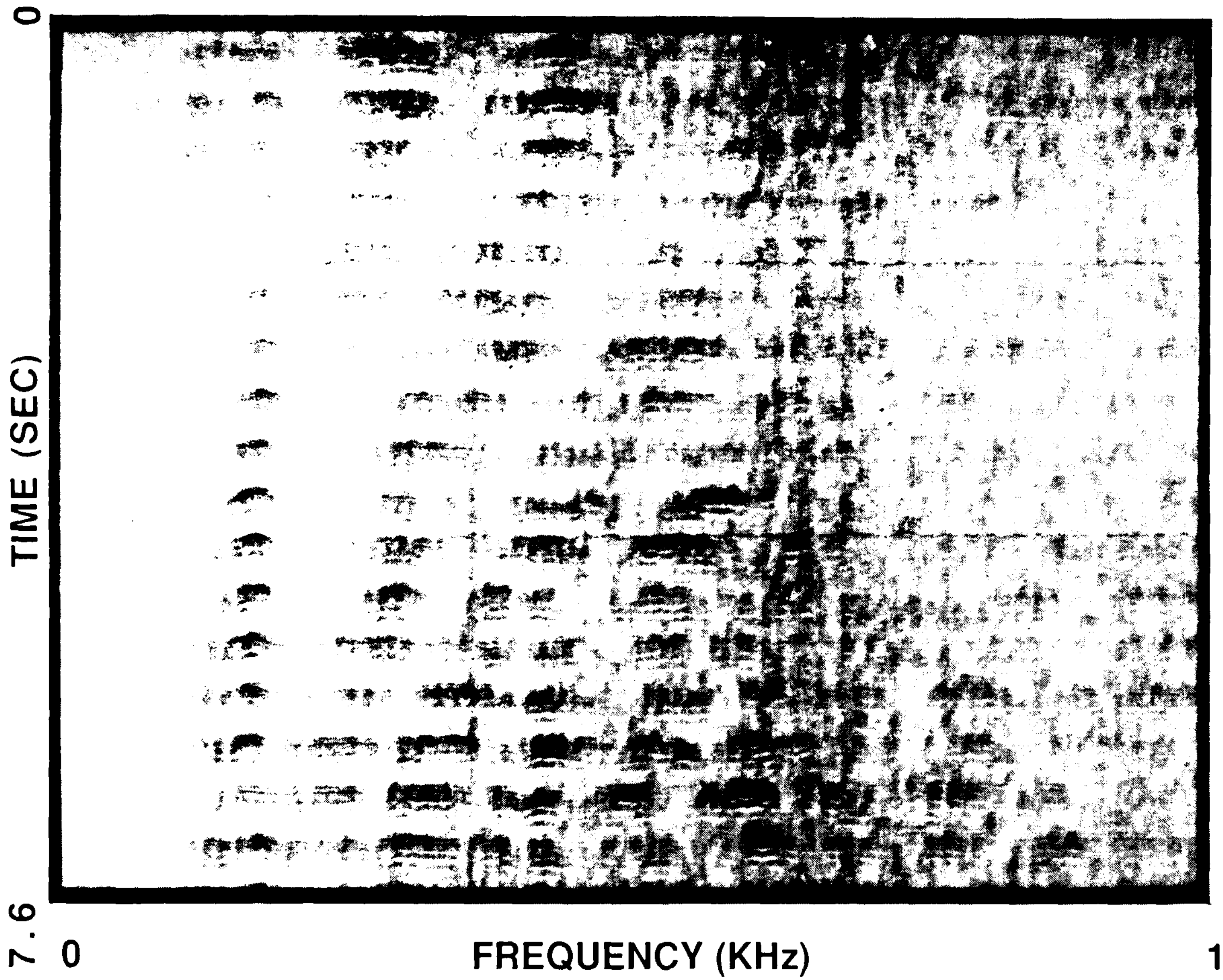


Gray whale, peak hold summation of 4 moans (32 sec., above), single moan waveform (below). AFB 0.75 Hz

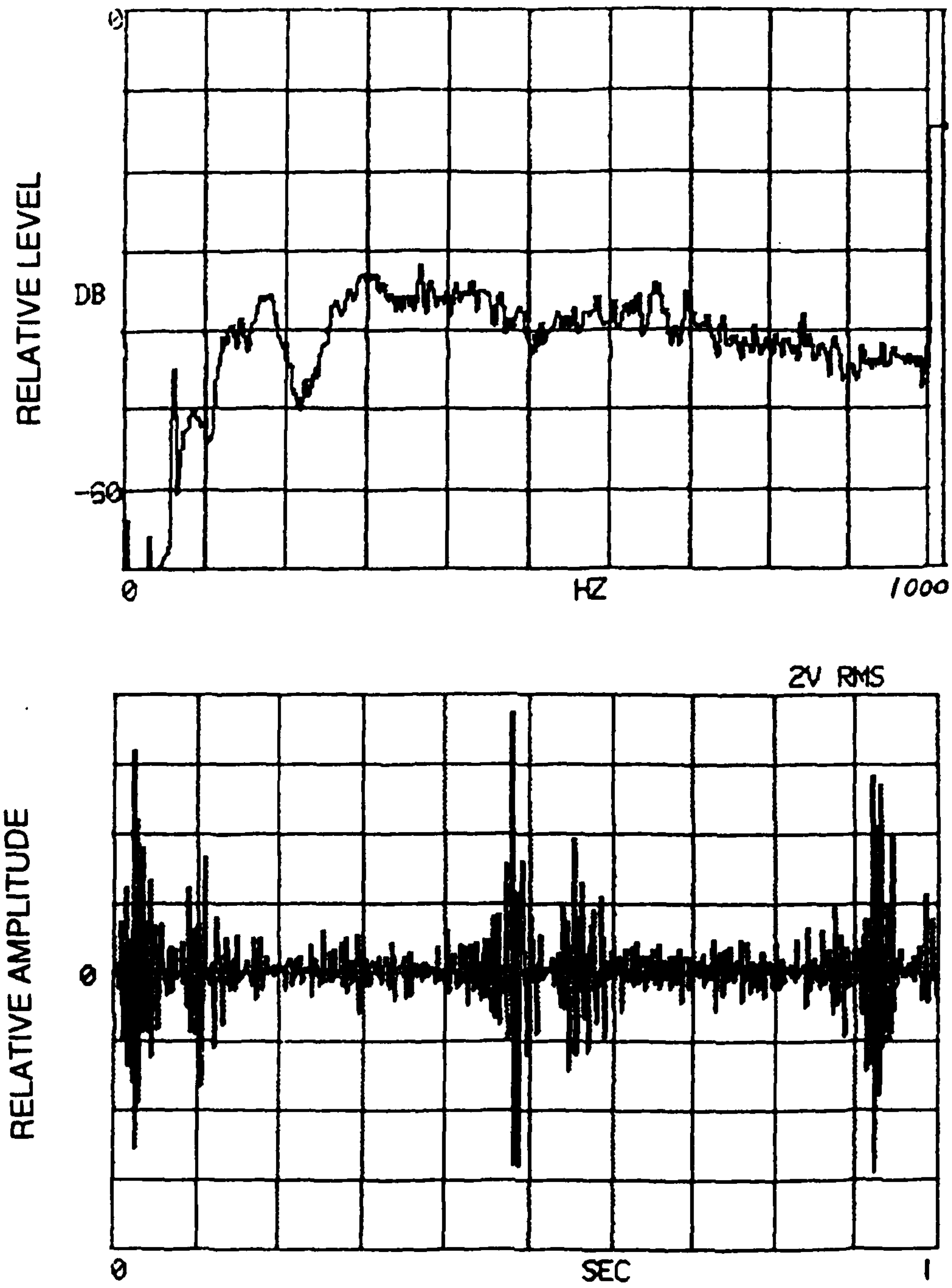
SOURCE	***MIW Minke Whale, Balaenoptera acutorostrata***
DISTRIBUTION	N Atlantic, to 77 deg., Labrador Sea, Davis Strait, Baffin Bay, Denmark Strait; Barents, Kara, Baltic, Norwegian seas; Central N Atlantic. N Pacific: edge of Beaufort Sea, Chukchi, Bering, Siberian, Okhotsk seas. Move N in summer for heavy feeding.
NUMBERS	NE Atlantic, to 186 thousand, unknown elsewhere. W Pacific-Okhotsk region, perhaps to 28 thousand, largely unknown in other Pacific regions.
LIFE HISTORY	Appearance: small streamlined rorqual (grooved), to about 10 m (8-10 tons). Color: dark dorsal (varies between black, brown, gray), light on undersides, white band across flippers (N hemisphere). Food: pelagic crustacea, a wide variety of small fishes (pelagic and demersal), e.g., mackerel, salmon, capelin, herring, cod, whiting, small sharks, haddock. Calving: in October-March when mating also occurs. Occurs singly or in small groups of 2-3 during winter months, larger pods on summer feeding grounds. Often attracted to ships, may stay near them for long periods. Predation: killer whales, man. As with most baleen whales, the minke moves N in summer to feed heavily, and S in winter for breeding. Seen among dense ice floes. 
TRANSIENT OCCURRENCE	Reported clicks at 6.8/sec. 200 clicks in 50 series. Varied and generally infrequent in occurrence.

TRANSIENT DATA

SUBJECT	**Minke Whale: downsweeps, grunts, ratchet sounds, pulse trains**
DATE	Unknown
LOCATION	Ross Island, Antarctica; NW Atlantic, Antigua
CONDITIONS	Many recordings made as the whales milled about the stationary ships.
TRANSIENT DESCRIPTION	Downsweeps modulate from about 115 or 130 Hz to about 60 Hz. Source levels to 165 dB. Duration is 0.2-0.3 sec. Grunts are 80-140 Hz with a source level of about 175 dB. Intervals between sounds, 8-97 sec (Ross Island). Low frequency grunts varied in frequency in the spectrum of 80-140 Hz, durations of 165-320 msec. They may occur in trains. Another category, "A Train", known to Navy sonarmen, has maximum energy at 100-200 Hz with highest frequencies near 2 kHz. These thumps are 50-70 msec in duration with trains exceeding 1 min duration. Ratchet sounds are centered at 850 Hz. Short trains or pings and clicks to 20 kHz. Source level of high frequency sounds, 151 dB. Not reknowned for sound production.
DATA SOURCE	E. Mitchell, H.E. Winn, W.E. Schevill, W.A. Watkins, T.J. Thompson
SERIAL	MIW



MINKE WHALE PULSE TRAIN (AFB-3.75 Hz)



Minke whale, peakhold spectrum of doublet pulse train (20 sec., above), waveform of 3 doublet pulses (below). AFB 3.75 Hz

SOURCE

SEW Sel Whale, Balaenoptera borealis

DISTRIBUTION

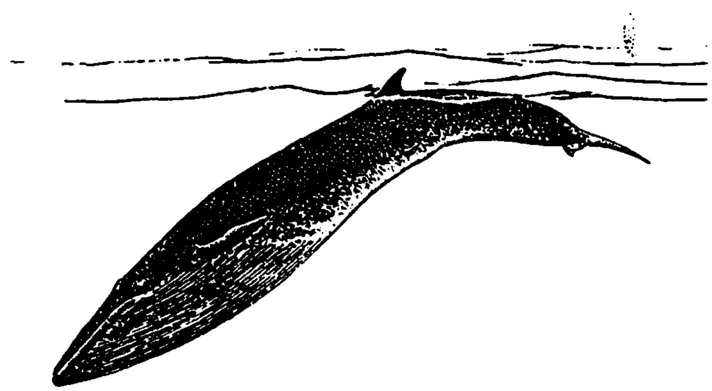
N Atlantic, to 79 deg. Off Spitzbergen, Norway, Finmark, Bear I., Novaya Zemlya; W Barents, SE Greenland, Labrador Seas, Davis and Denmark straits. N Pacific: Gulf of AK, Bering Sea. Does not venture as far N as other rorquals in summer.

NUMBERS

To 2000 off Nova Scotia; 1000, Labrador Sea; to 2000, off Norway. Other N Atlantic areas unknown. Estimates for N Pacific, as high as 42000.

LIFE HISTORY

Size: to 19 m (30 tons), smaller in some regions. Appearance: large, pointed, long dorsal fin, noticeably larger than fin (finback) whale. Color: dark gray, changing to bluish on sides, light underneath, whitish scars on sides. Longevity: to 60 yrs. Food: crustacean plankters, e.g., euphausiids, amphipods; small fishes including mackerel, anchovy, saury. Usually found in pods of 6-7 animals. Swims to 22 km/hr, for short thrusts. Dive: shallows characteristically, fin and head descend at once rather than head and arched back as in other rorquals. Calving: and mating in more temperate regions, winter; one calf about every other year. Moves northward in summer for heavy feeding.



TRANSIENT OCCURRENCE

Sounds unknown, only Baleen whale yet unrecorded with certainty. Probably makes variable low frequency moans.

SOURCE
FIW Finback Whale, Balaenoptera physalus

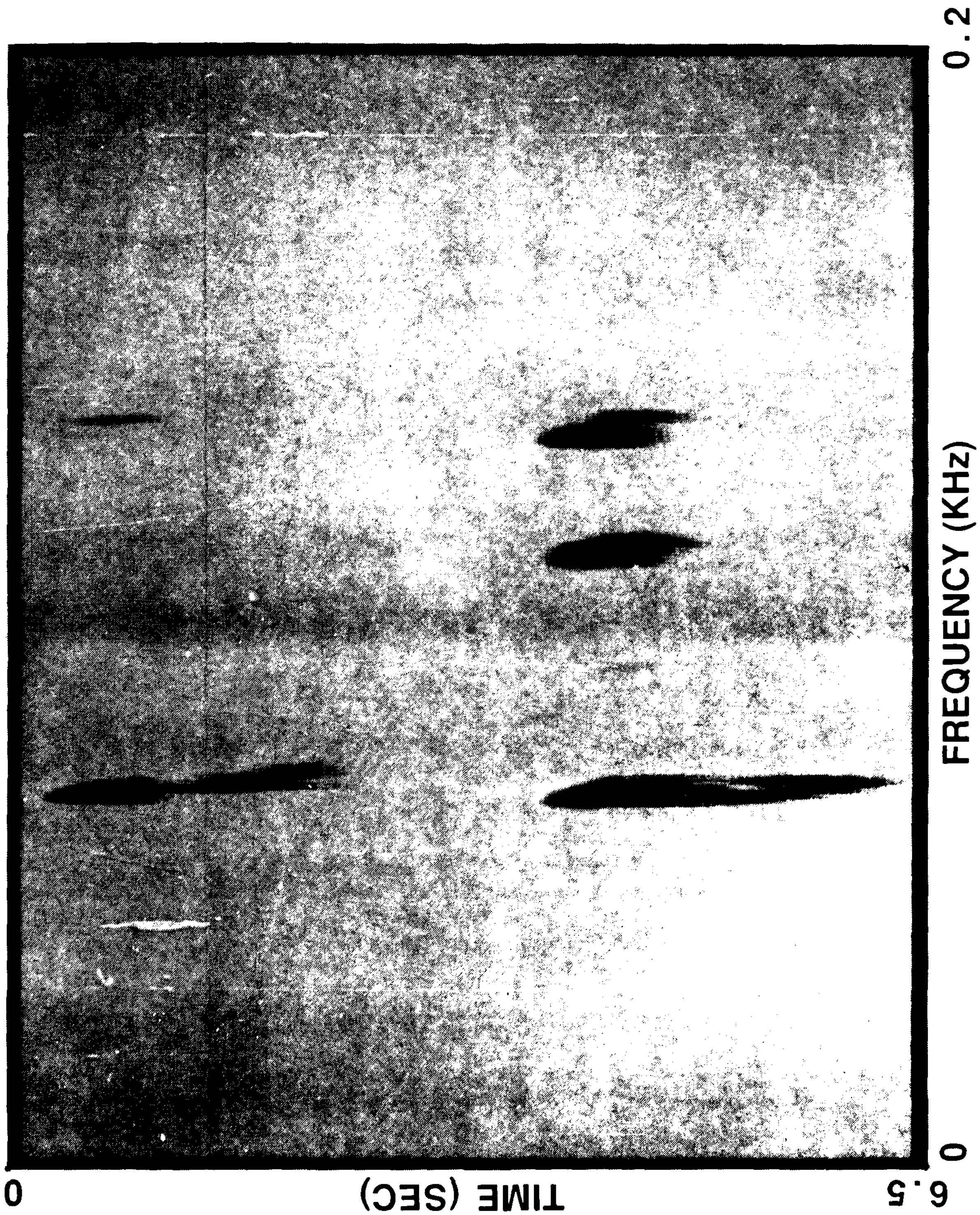
DISTRIBUTION
N Atlantic, to 80 deg; Baffin Bay, Davis Strait; Labrador, Greenland, Barents, Norwegian seas. Off Spitzbergen, Norway, Iceland. N Pacific: Okhotsk, Bering, Chukchi seas, into Arctic Ocean. N-S annual migrators to edge of ice.

NUMBERS
Perhaps 10-15 thousand, Arctic and sub-Arctic (Atlantic-Pacific).

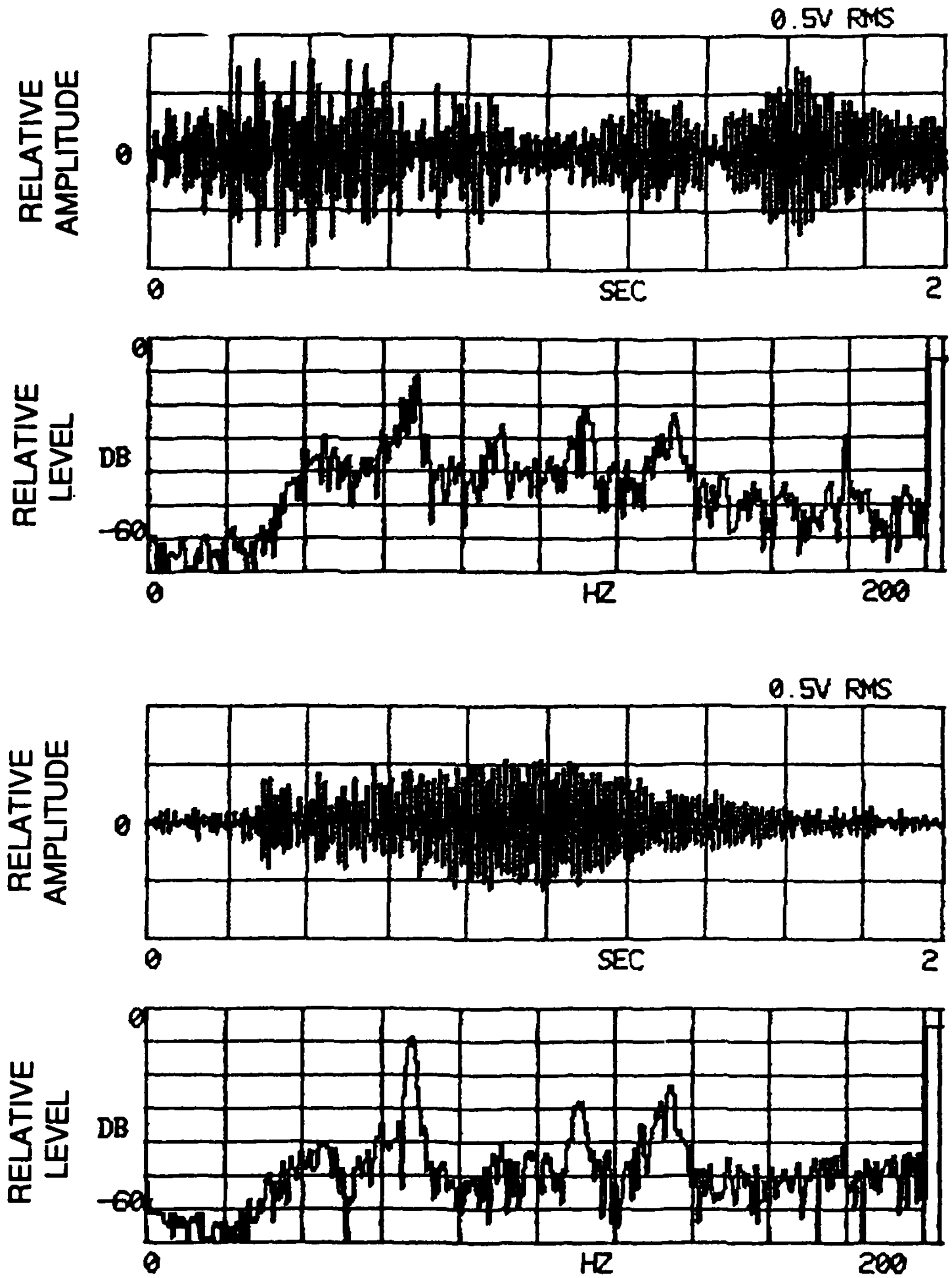
LIFE HISTORY
Size: to 27 m (160 tons), second largest whale (to blue). Appearance: slender, streamlined, strongly falcate dorsal fin, hence the common name. Color: dark gray dorsally, lighter down sides to white underneath. Distinguishing identifying characteristic is whitish lower jaw, on right side only, which shows when whale is moving fast at the surface or is spyhopping. Longevity: perhaps to 100 yrs. Food: planktonic crustacea, e.g., amphipods, euphausiids, small fish, e.g., capelin, cod, herring, mackerel; squid. Swims about 10 km/hr. Moves long distances in short periods of time, e.g., in the Arctic, one tagged whale traveled 2095 km, 292 in one day. May occur in groups of 2-20; or in heavy feeding areas, up to 100 may be seen. Predators: man, killer whales, sharks, swordfish, parasites.

TRANSIENT OCCURRENCE
Frequent moans, irregular intervals. Trains of 20-Hz pulses in rigidly spaced intervals raise ambient noise, ocean-wide.

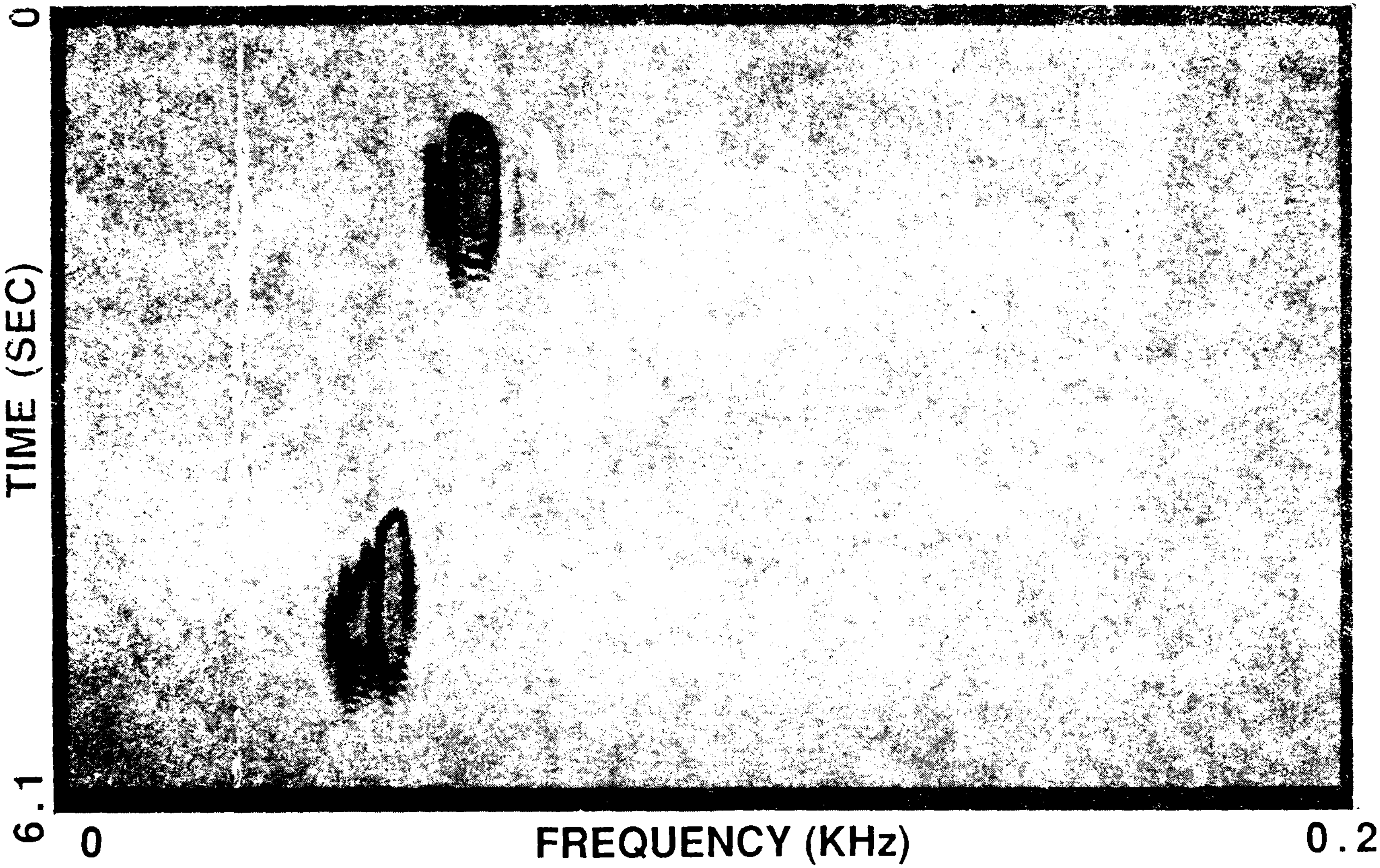
SUBJECT	**Finback Whale: long and short low frequency moans, short 20-Hz pulses**
DATE	June 1969 (moans), December 1966 (pulses)
LOCATION	Gulf of California (moans); 90 nm W of Los Angeles (pulses)
CONDITIONS	Moderate - calm seas. Numerous whales in sight, feeding on pelagic crabs. Whale movements slow, except in transit when they reached 14 nm/hr (moans). High seas (pulses).
TRANSIENT DESCRIPTION	Long moans appeared in doublets, a 1.9 sec component centered at 68 Hz and a 1.6 sec component at 34 Hz. Of two contacts, 365 long moans occurred at rate of 1.6 (one whale) and 2.2 (other whale) times/min. Although not recorded in Arctic waters these sounds are representitive of the only moaning-type sounds available from the Pacific. Short moans appear in miscellaneous forms with much of the energy in the 20-100 Hz region, virtually none above 200 Hz. Measured source levels, 159-183 dB. 20-Hz pulses appear in pairs with a slight frequency shift between members of a pair. Pulse source levels noted as high as 181 dB. They may appear in trains lasting for hours. The pulses have been noted all along the west coast of U.S., from Alaska to Mexico. They are more frequent in winter and spring months.
DATA SOURCE	W.C. Cummings, P.O. Thompson, W. Watkins, W. Schevill, P. Edds
SERIAL	**FIW**



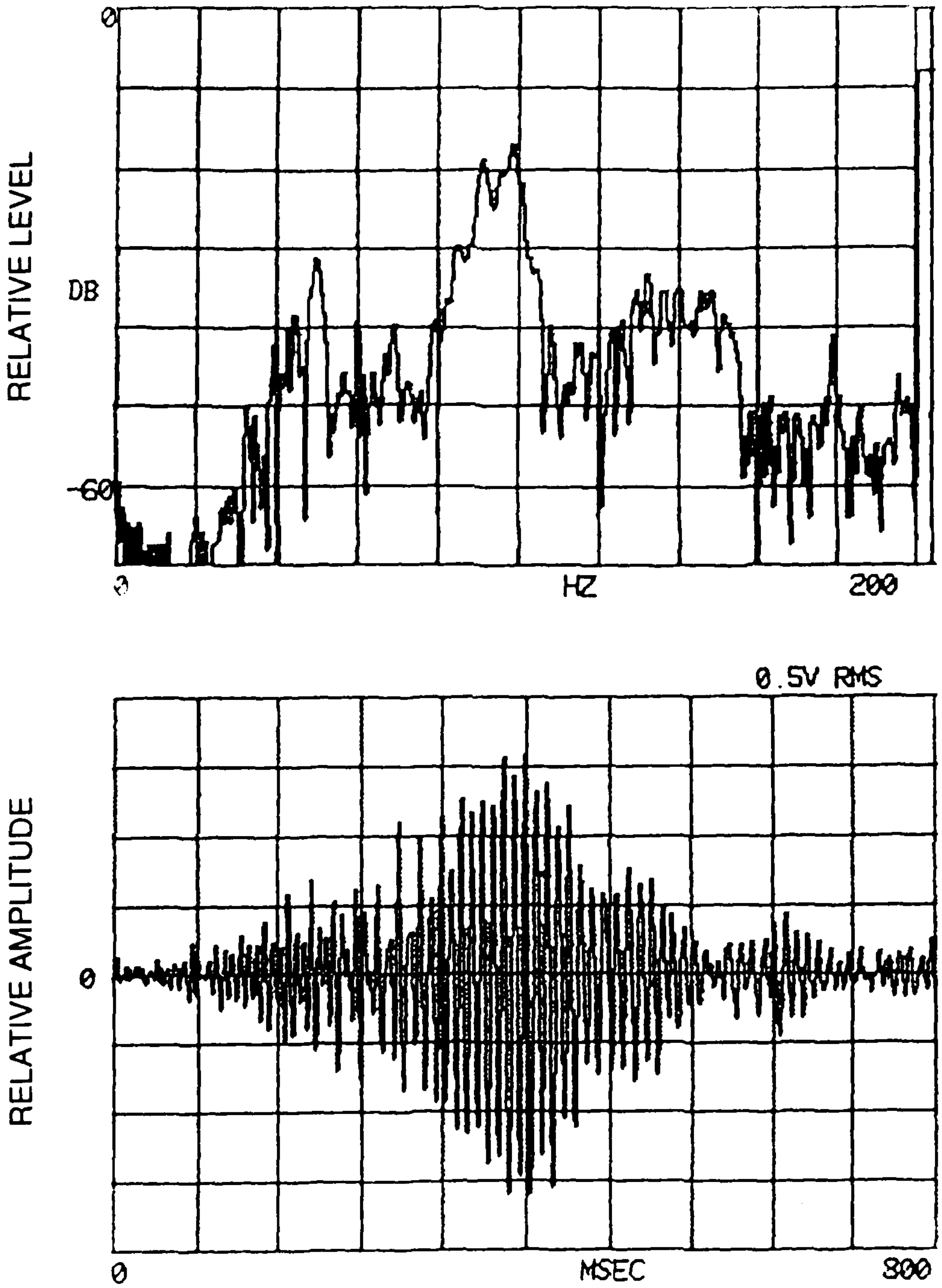
FINBACK WHALE LONG MOANS (AFB-0.75 Hz)



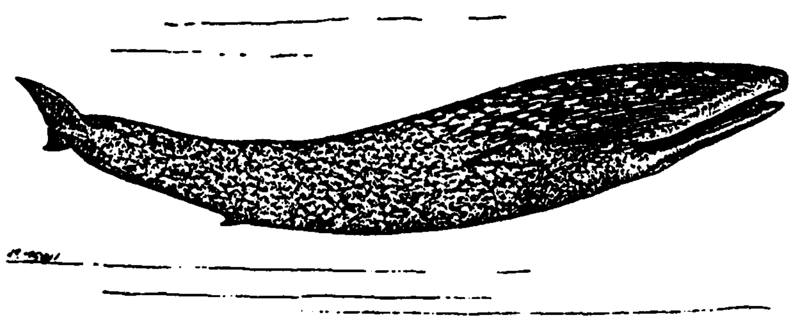
Finback whale, wavefoam and spectrum of long simple moan (above), same of long complex moan (below). AFB 0.75 Hz



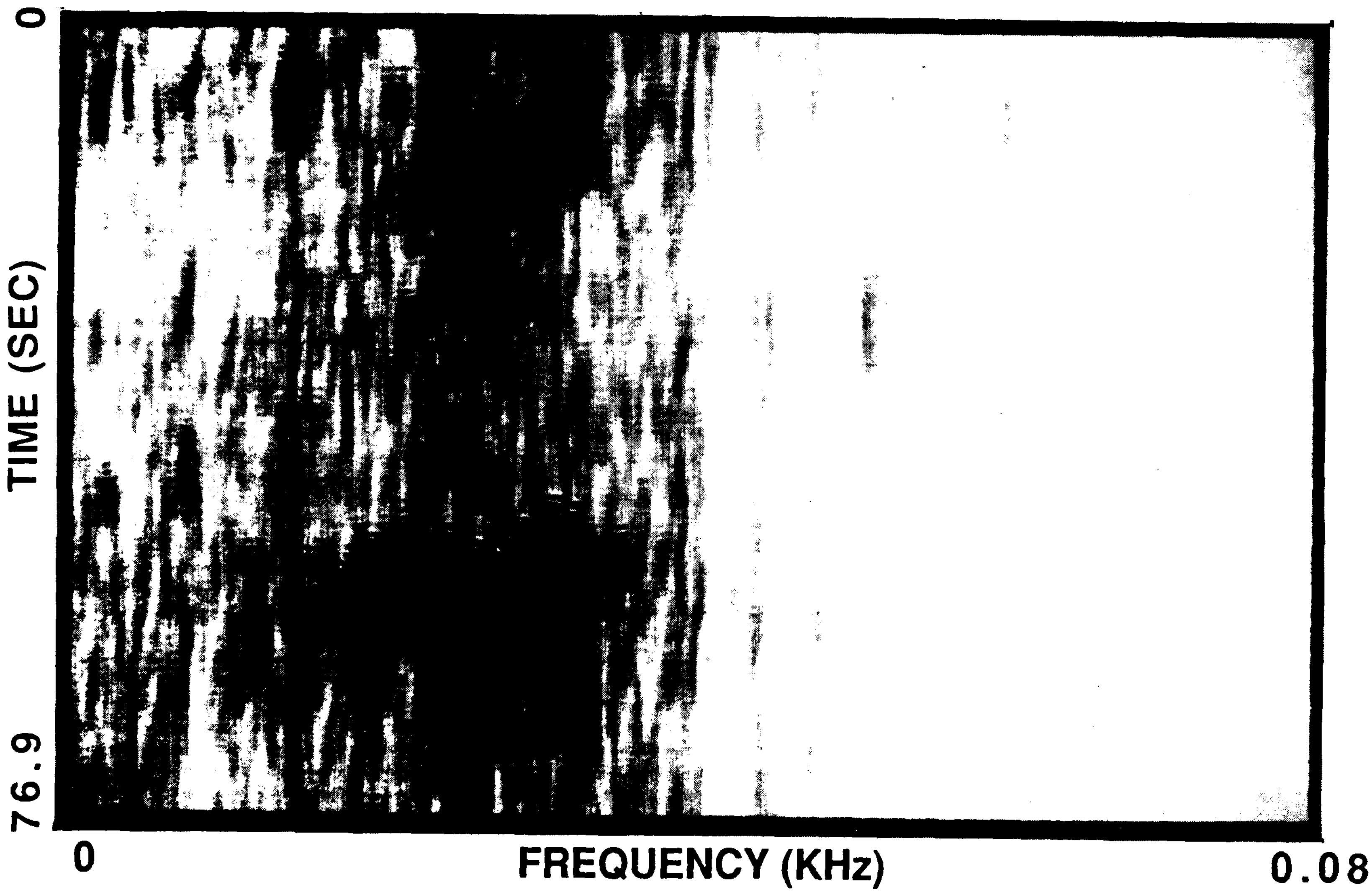
FINBACK WHALE SHORT MOANS (AFB-0.75 Hz)



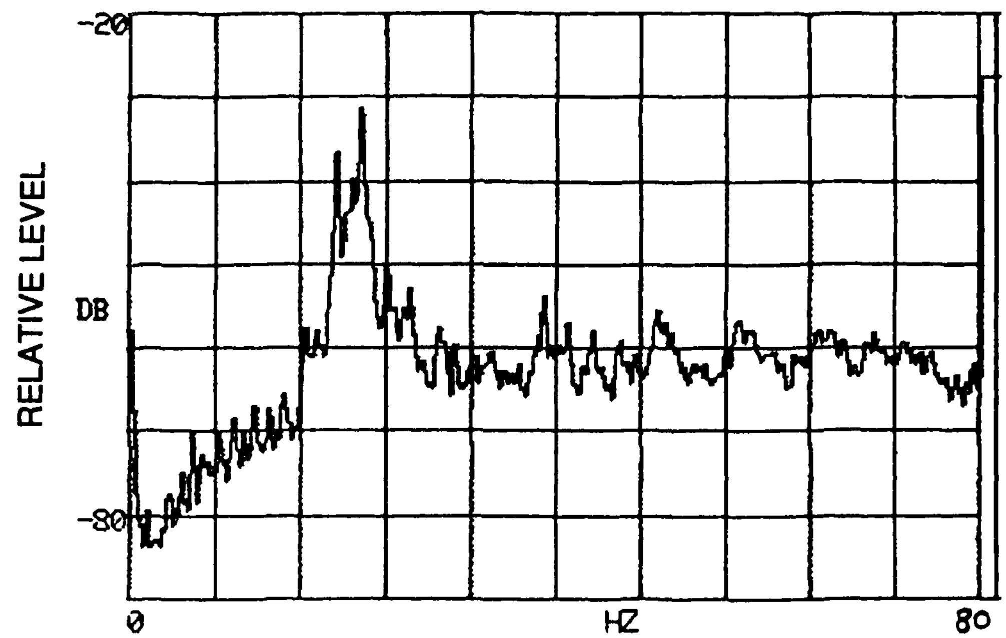
Finback whale, spectrum of short moan (above), short moan waveform (below). AFB 0.75 Hz

SOURCE	***BLW Blue Whale, Balaenoptera musculus***
DISTRIBUTION	N Atlantic, to pack ice. S Greenland, Baffin Bay, Davis Strait, Labrador Sea, Spitzbergen, N Barents Sea to 80 deg N. N Pacific: summer, Gulf of AK, Aleutians. Kurils, Okhotsk, Kamchatka. Uncommon in Bering and S Chukchi. N-S seasonal migration.
NUMBERS	Unknown. Speculated at 200, probably more than 2000.
LIFE HISTORY	Largest living animal species, to 34 m (190 tons). Color: bluish gray with light undersides, whitish mottling on some. Appearance: long, slender whale compared to right or bowhead whales; proportionally, very small dorsal fin. Calving: each 2-3 yrs. Longevity: to 80-90 yrs. Food: almost entirely krill (large euphausiid crustaceans), also including amphipods, pelagic crabs, small fish. Second fastest swimmers among great whales (after sei): to more than 30 km/hr. Often appears singly, but in large feeding concentrations as many as 10 in a group. 
TRANSIENT OCCURRENCE	N Pacific: fall and winter, long series of moans at regular intervals. Elsewhere, same phenomena, but different signals.

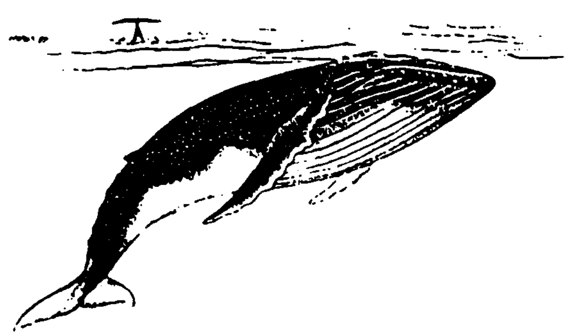
SUBJECT	**Blue Whale: moans**
DATE	June 1970, fall and winter 1965-1971
LOCATION	Coast of Chile, offshore of western coast of U.S., Alaska-Mexico
CONDITIONS	Chile: small embayment, moderate chop, daylight hours, air temperature of 2 deg C. U.S. offshore, varied conditions, day and night.
TRANSIENT DESCRIPTION	Chilean moans occur in series up to 37 sec in duration, and actually are composed of 3 moans. The sequence of 3 is repeated, sometimes for hours on end from a single source. Duration from the start of one sequence to the next averages 108 sec, but intervals may be as long as 300 sec when the animal surfaces to breathe. Energy is at frequencies as low as 12.5 Hz, strong harmonics as high as 200 Hz. A low frequency whistle (390 Hz) occurs just before last moan element. Overall source levels are up to 188 dB in the 14-222 Hz band. Most energy is centered at 20, 25 and 31.5 Hz 1/3 octave bands with secondary components at 50 and 63 Hz 1/3 octave bands. Sequences of moans are repeated for hours at a time. No. Pacific moans also appear as pairs (doublets) with each member about 19 sec in duration. They occur as intense choruses, beginning in Sept of each year and lasting to Nov. The first member has broader bandwidth, about 10 Hz centered on 20 Hz. The second is nearly pure tone, centered on 20 Hz, with a brief 2 Hz lowered "tail" at the ending. At the peak of the long 20-Hz signal season, these choruses dominate the low frequency ambient noise. Source levels are believed to exceed 180 dB.
DATA SOURCE	W.C. Cummings, P.O. Thompson, P. Edds
SERIAL	BLW



NO. BLUE WHALE MOANS (AFB-0.3 Hz)

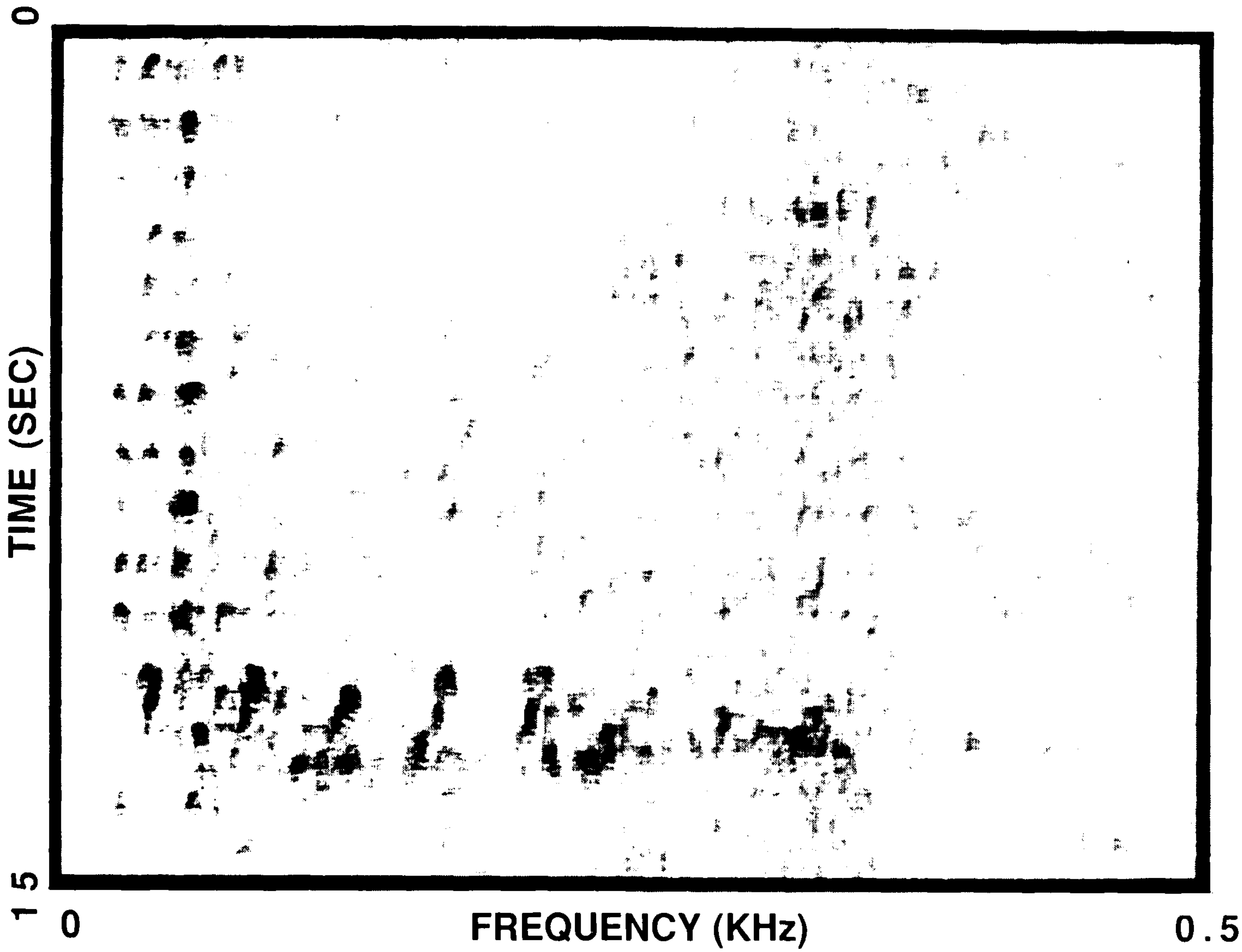


No. blue whale, spectrum of long 20 Hz moan (56 sec. average). AFB 0.3 Hz

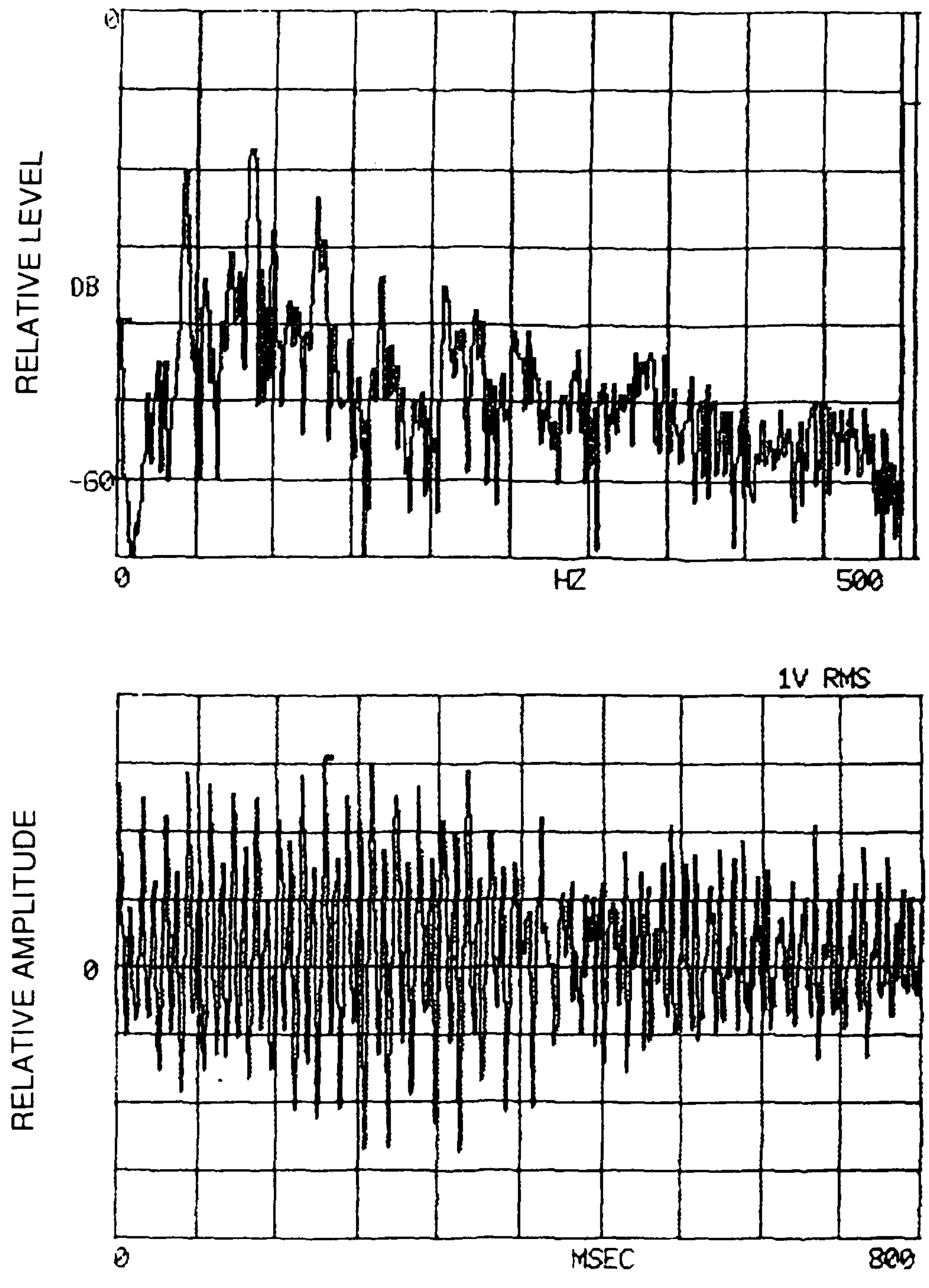
SOURCE	***HUW Humpback Whale, Megaptera novaeangliae***
DISTRIBUTION	W and E boundaries of N Atlantic, N Pacific. Off Novaya Zemlya, Finmark, Spitzbergen, Iceland, Greenland, and Newfoundland; Norwegian Sea, Labrador Sea. Pacific: Chukchi Sea to Kamchatka, Sea of Okhotsk, SE Alaska. N-S migraters.
NUMBERS	NW Atlantic, about 6000. NE Atlantic, hundreds. N Pacific, perhaps more than 2000. As with all whales, large and small, except for NE Pacific bowhead, population size is poorly known.
LIFE HISTORY	Size: to about 14 m (35 tons). Appearance: round knobby head, rotund body, huge flippers (to 1/3 body length); small, slightly falcate (sickle-shaped) dorsal fin. Longevity: 48 yrs. Gestation: 11 mo., one calf about every 2 yrs. Color: blackish, varying amounts of white, especially on underside, flippers may be white on upper side, flukes with varying degrees of white on underside. Food: krill (euphausiids), herring, capelin, mackerel, sand lance, occasionally benthic animals. Surface acrobatics-lobtailing, flipper slaps, spectacular breaching. Can show aggression against boats by charging them; attacks with flukes are reported. Can attain speed to 27 km/hr, usually 4-14. Dive: 30 min, usually 5-8, to at least 20 m. Average 68 breaths/hr. May run with minke or finback whales, or with white sided or Dall's porpoises. Predators: man, killer whales, sharks, parasites. 
TRANSIENT OCCURRENCE	Variable sound occurrence, except for monotonous repetitions of wailing sounds (songs) on winter breeding grounds.

TRANSIENT DATA

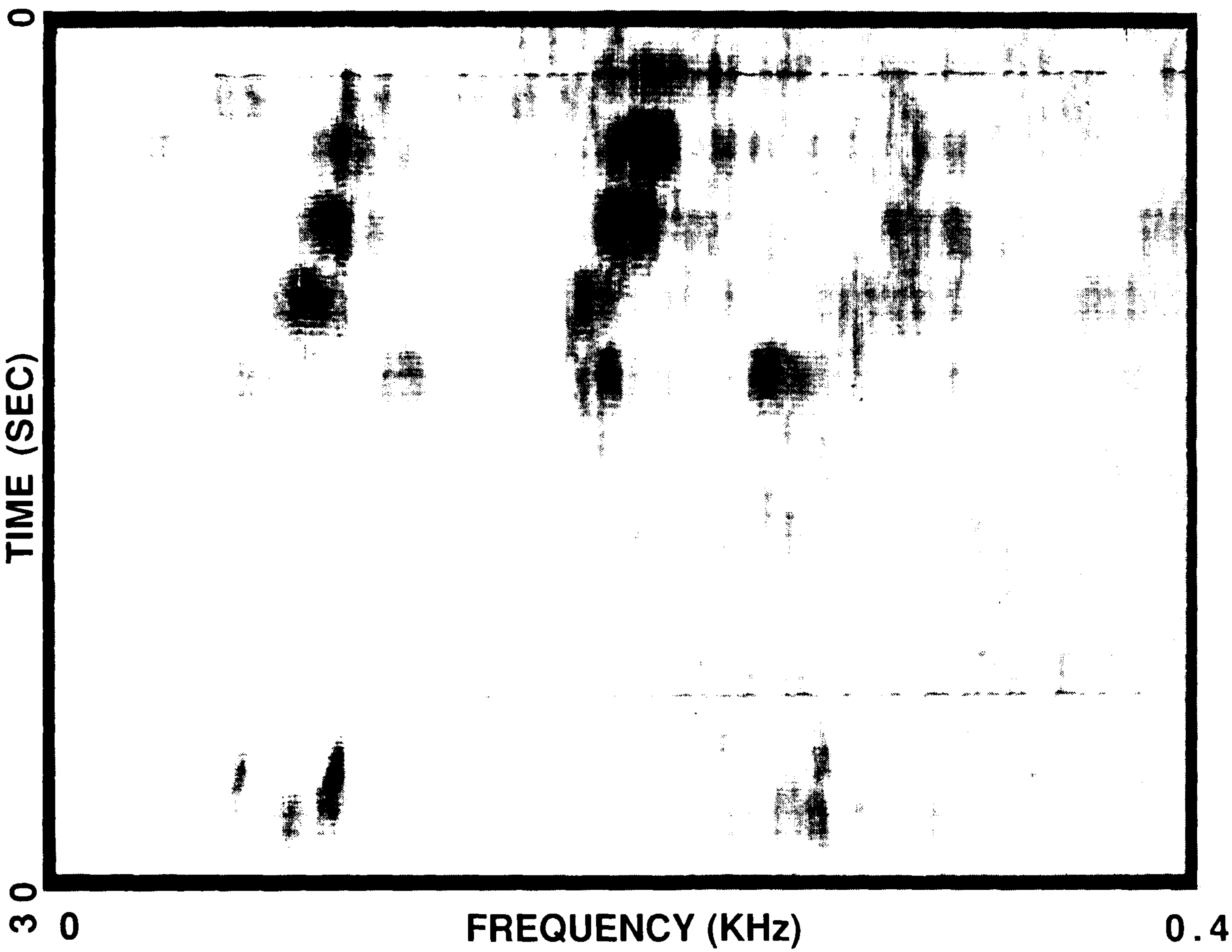
SUBJECT	**Humpback Whale: moans, grunts, pulse trains, blow-hole associated sounds, surface impacts, songs**
DATE	August 1975, March 1977
LOCATION	SE Alaska (moans, etc); Maui (songs)
CONDITIONS	Calm protected waters, archipelago (Alaska); calm - sea state 3 open water (off Maui)
TRANSIENT DESCRIPTION	Moans and grunts are 20-1900 Hz. Moans may be simple (harmonic structure) or complex (of a pulsed nature). Major energy in pulse trains is in the band from 25-80 Hz with pulse duration of 300-400 ms. Associated with all pulse trains was an unusual spread spectrum "whoosh", 40-1250 Hz, made during spiral feeding maneuvers. This sound is associated with explosive bursts of bubbles. Blowhole associated sounds (as whales encounter one another) are shrieks (555-2000 Hz) and trumpet blasts, fundamental at 414 Hz. Surface impacts are from flipper or fluke slaps on water's surface, sequences of 3-25 sounds. Source levels range from 162 (low frequency pulses) to 192 dB (impacts). Songs heard mostly in sub-tropical waters during the winter breeding season, but rarely are heard off Alaska just before southward migration. They are repeated sequences that may last to 30 min, the whole being repeated again and again, to nearly a full day. It is doubtful if these sounds will be encountered in Arctic waters.
DATA SOURCE	W.C. Cummings, P.O. Thompson, W.A. Watkins, R. Payne, many others
SERIAL	HUW



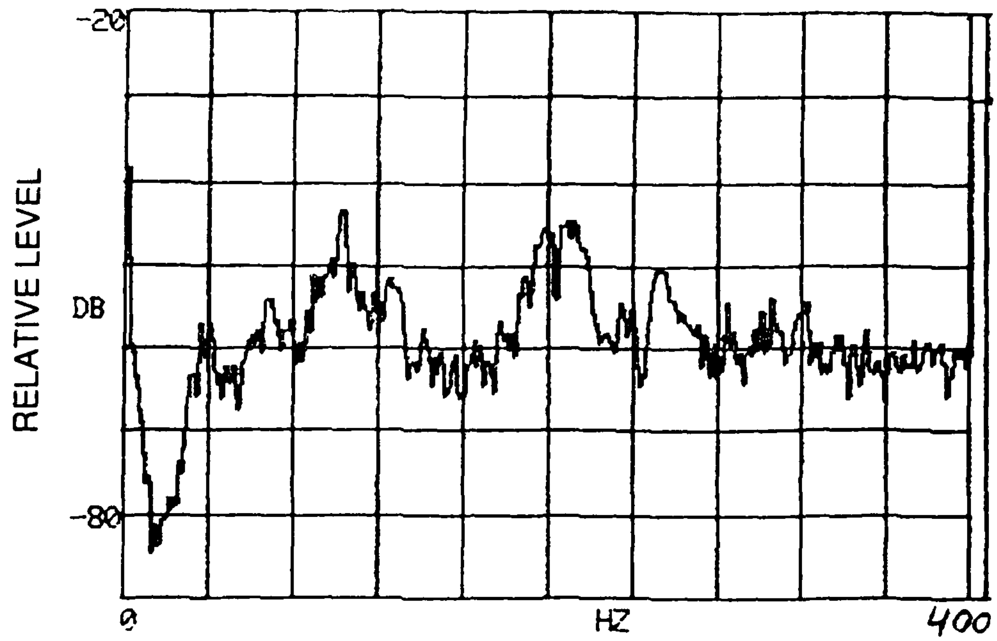
HUMPBACK WHALE GRUNTS, MOAN (AFB-1.88 Hz)

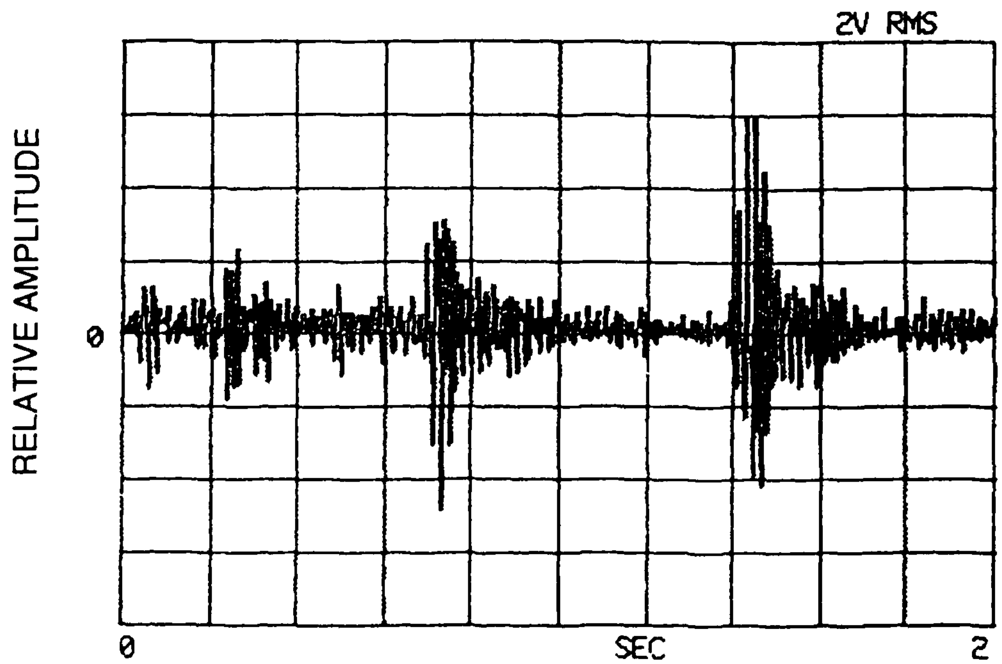


Humpback whale, spectrum of single moan in northern waters (above), moan waveform (below). AFB 1.88 Hz



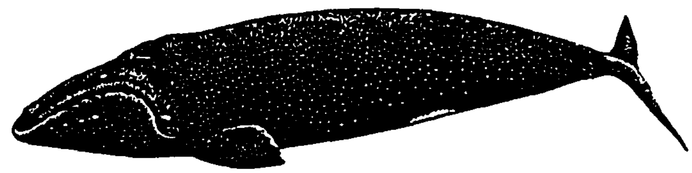
HUMPBACK WHALE GRUNTS, MOAN (AFB-1.5 Hz)





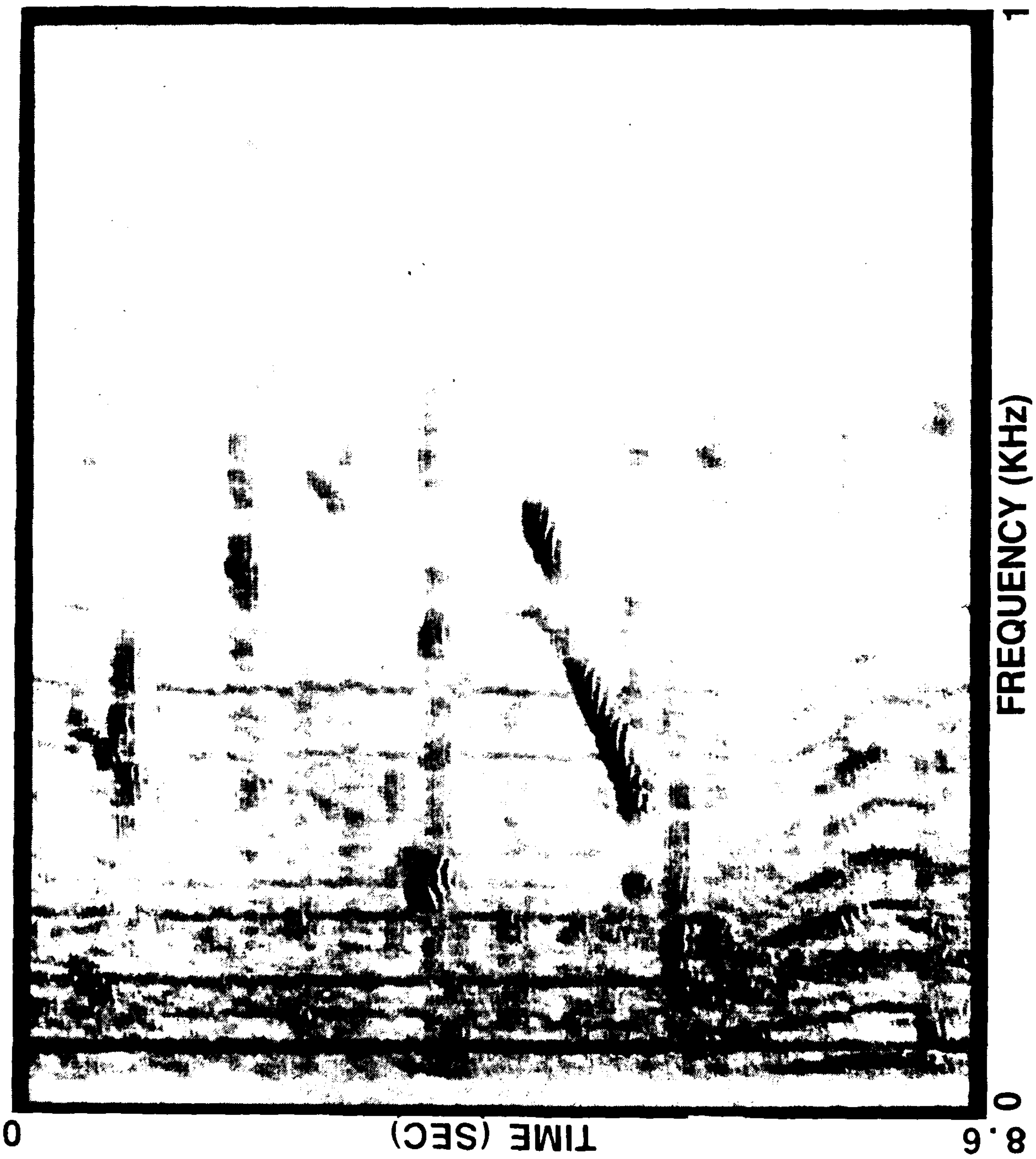
Humpback whale, spectrum of 5 grunts (4.7 sec. average, above), waveform of 4 grunts (below). AFB 1.5 Hz

SUPPORTING DATA

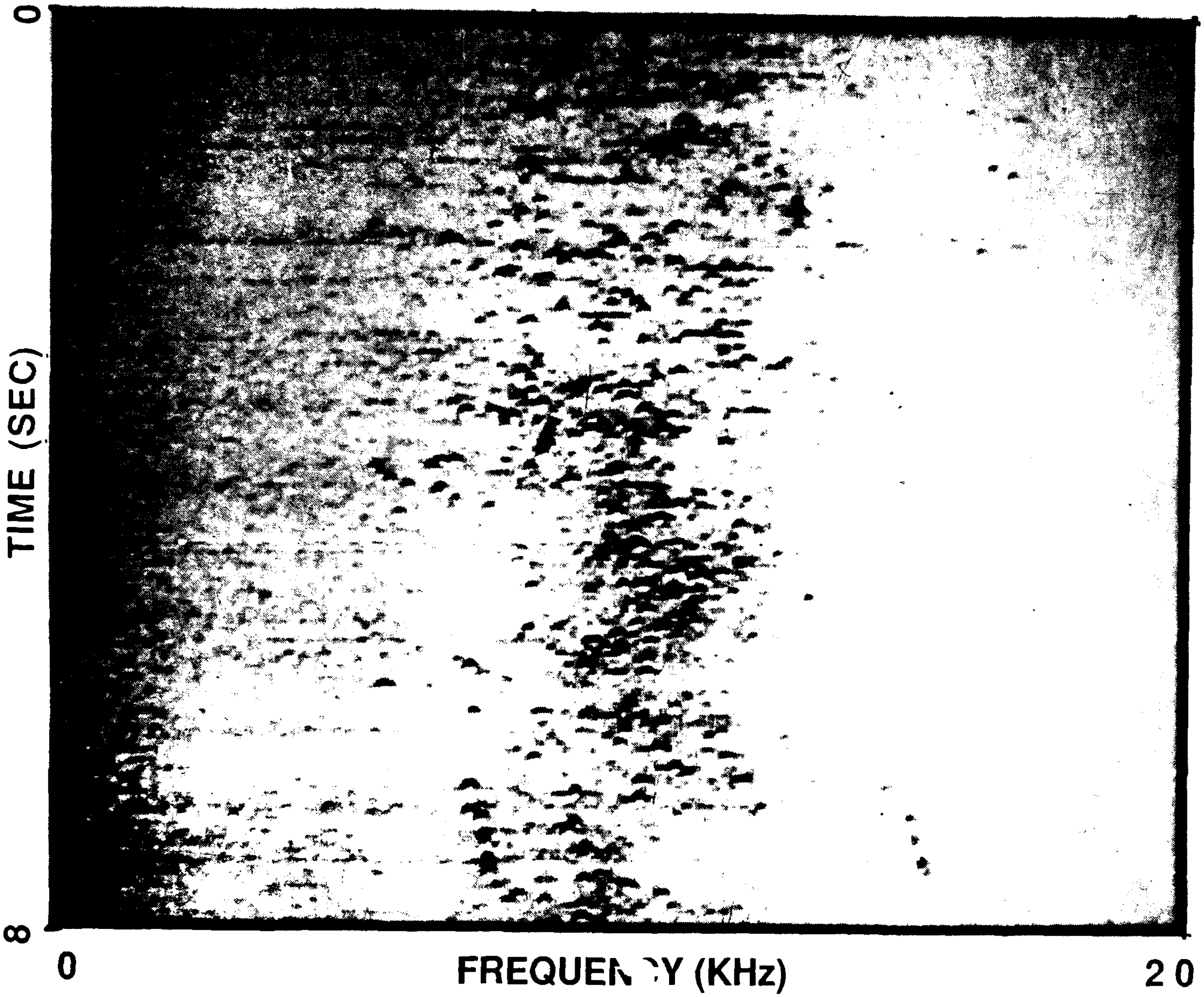
SOURCE	***RIW Right Whale, Eubalaena glacialis***
DISTRIBUTION	N Pacific: 25-60 deg; N Atlantic: 30-75 deg, populations completely separate. Move from Arctic regions with advancing ice. SE Greenland, W Labrador, Spitzbergen-Norway. Gulf of AK, Bering Sea on East; Kamchatka, Okhotsk on W.
NUMBERS	To a few hundred in N Atlantic, perhaps to 220 in N Pacific, mostly unknown, population drastically reduced.
LIFE HISTORY	Size: to 18 m (100 tons). Appearance: rotund, no dorsal fin or throat grooves, huge lower jaws- baleen to nearly 3 m long. Color: uniformly blackish, except for light patches at bonnet (top of head) and variably on sides and belly. Calving: December-March, mostly in protected bays and lagoons; probably one calf each 2 yrs. Food: small crustaceans, e.g., copepods, krill, pelagic crabs. Produces a characteristic V-shape blow. Sometimes very docile near ships, even attracted to them. Can be very aggressive when molested or threatened. In days of intense whaling, the "right" whale to catch because it was big, laden with oil, had priceless baleen yield (enough to provision a whaling ship for several years), and floated when dead. 
TRANSIENT OCCURRENCE	Sounds are frequent and variable. Diurnal periodicity not noted. Most common during breeding season.

TRANSIENT DATA

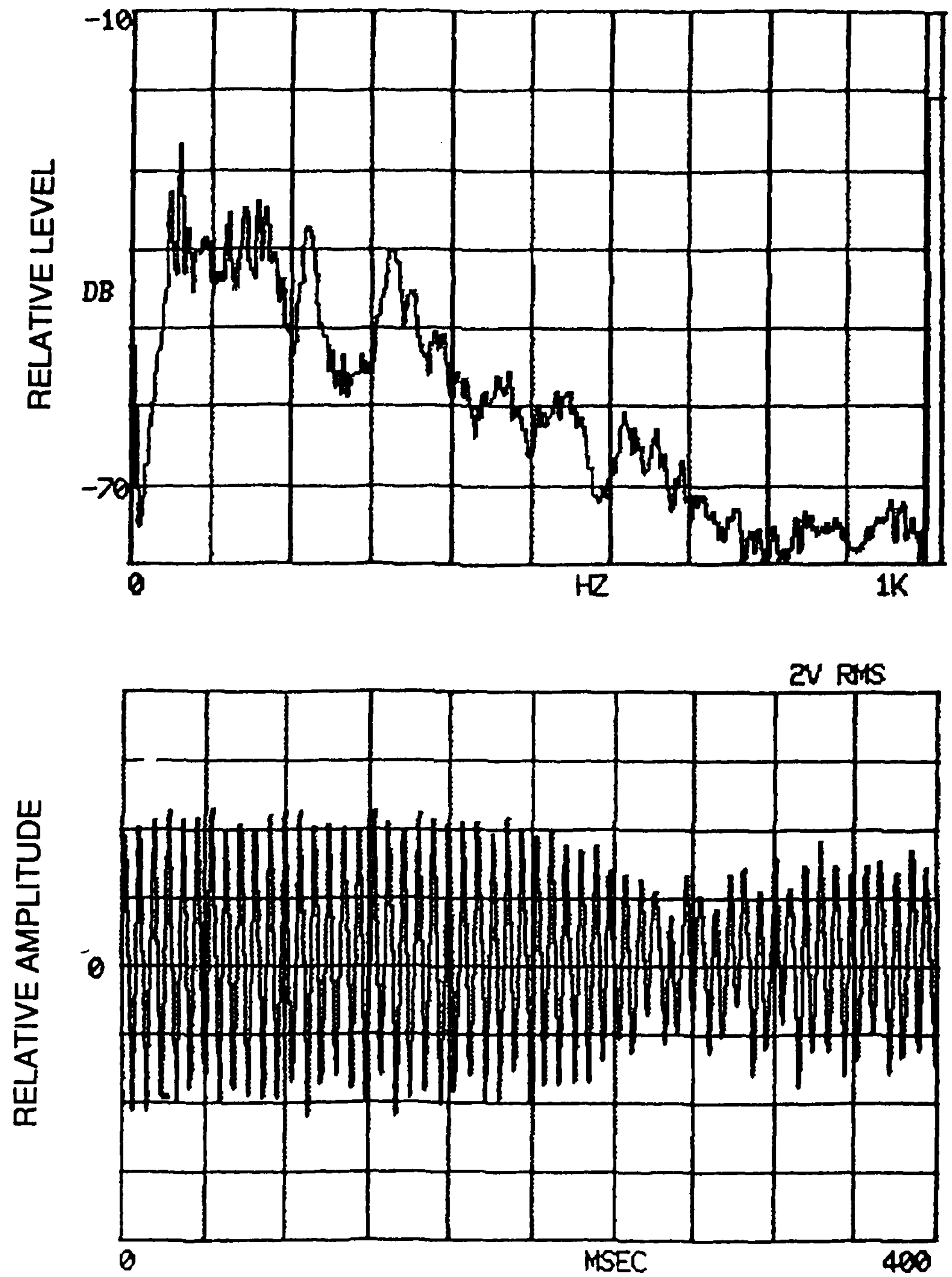
SUBJECT	**Right Whale: moans, belches**
DATE	April, year unknown
LOCATION	3 km off Martha's Vineyard Island, MA
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	The sounds are mostly moan or low-frequency "belch" type, below 1 kHz. Energy could be detected as low as 50 Hz. It appears that the lowest frequencies were less, and the analyzed recording may have been limited by rolloff in the low-frequency response. Some moans appear to be of a pulsed nature, others were composed of simple tonals with harmonics. Most sounds have the principal energy below 500 Hz. Aurally, these sounds strongly resemble many of those produced by southern right and bowhead whales, to which this species is related. Right whale sounds have been encountered during U.S. Navy operations off Newfoundland, but the recordings are unavailable. Based on what is known about bowhead and southern right whales sounds, maximum overall source levels would exceed 185 dB.
DATA SOURCE	K. E. Schleicher, W.E. Schevill, W.A. Watkins, W.C. Cummings
SERIAL	RIW



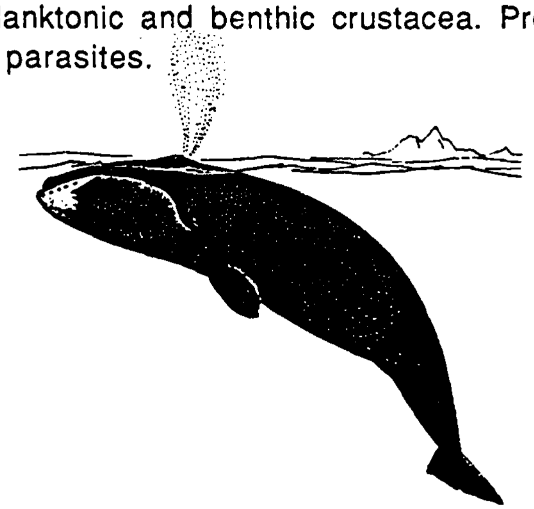
NO. RIGHT WHALE MOANS (AFB-3.75 Hz)



STRIPED PORPOISE WHISTLE CHORUS (AFB-75Hz)

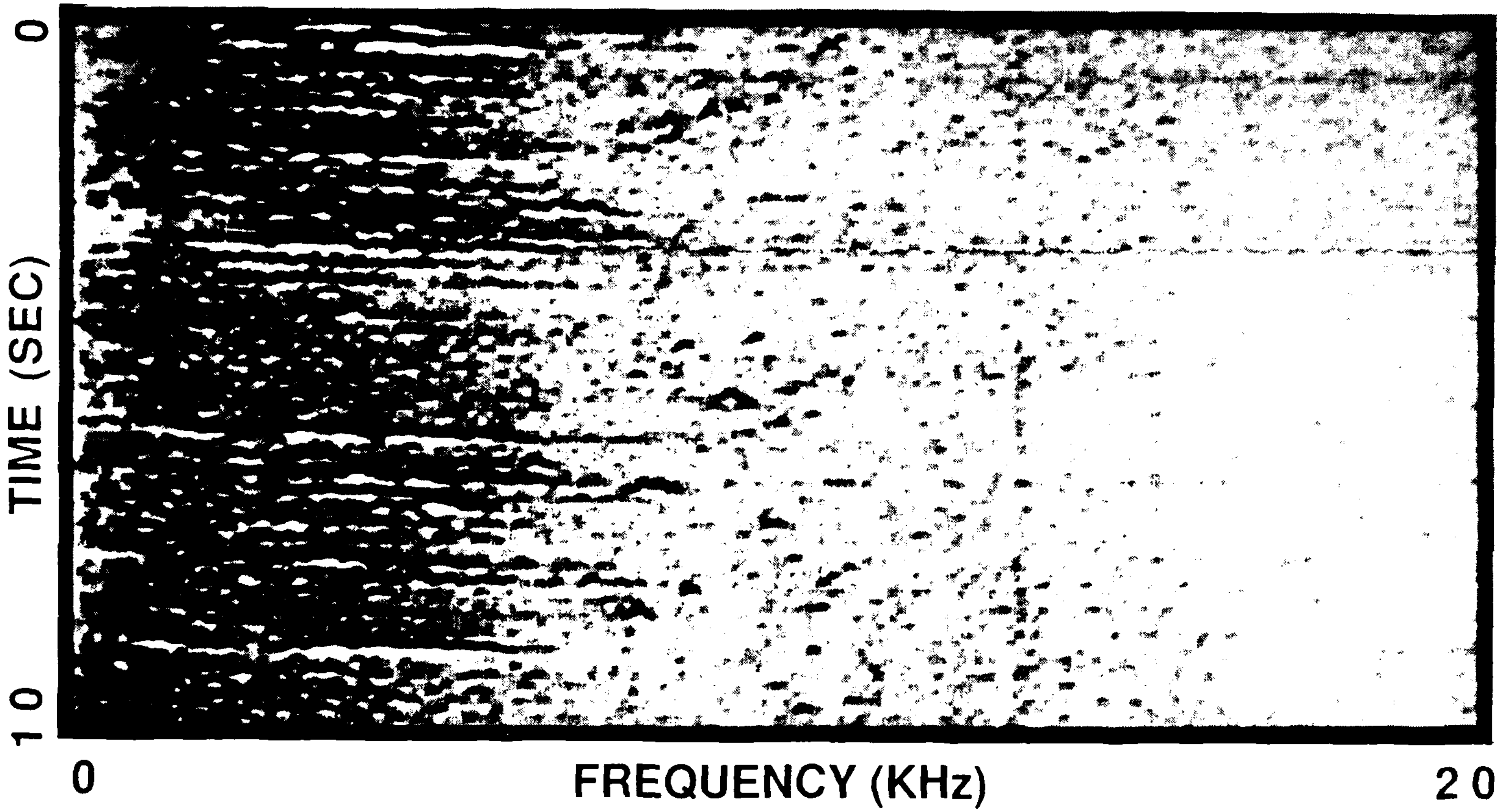


No. right whale, spectrum of 4 moans (4.5 sec. average, above), single moan wavefoam (below). AFB 3.75 Hz

SOURCE	***BOW Bowhead Whale, Balaena mysticetus***
DISTRIBUTION	N Atlantic, 60-80 deg; Baffin Bay-Spitzbergen-Franz Josef Land-Novaya Zemlya, S to James Bay. N Pacific: Beaufort, Chukchi, Bering seas; Okhotsk Sea. Only true ice baleen whale. Winters near edge of ice, summer migration to pack ice edge.
NUMBERS	Best estimates for W Arctic region, 4000. World-wide, perhaps 10-12 thousand.
LIFE HISTORY	Size: to 18 m (92 tons). Appearance: like right whales, very rotund for body length, no dorsal fin, no ventral grooves, no bonnet (as in right whales), very wide flukes. Color: dark brown or black with whitish patches on chin or lower jaw, sometimes white patches on or near tail stock and undersides. Baleen to nearly 5 m long, such that the lower jaw "bows" upward. May break through ice to 15 cm thick. NE Pacific group feeds heavily in far E Beaufort. Normally seen in groups of 2-50. Calving: about one every 2 yrs, born in spring months. No indication of any attraction to boats, may be very aggressive when hunted. Dive: to nearly 1 hr, normally 3-6 min. Swims to 7 km/hr. Food: planktonic and benthic crustacea. Predation: man, killer whales, parasites. 
TRANSIENT OCCURRENCE	Diurnal periodicity, irregularly occurring moans. Songs at regular intervals (mean duration, 66 sec, with 6 phrases each).

TRANSIENT DATA

SUBJECT	**Bowhead Whale: moans, song sequences, gargle-like utterances**
DATE	30 April-22 May 1982
LOCATION	Beaufort Sea, off Barrow, AK, out to 18 km offshore.
CONDITIONS	Apparently 10/10 ice cover to wide (2 nm) leads, wind to 40 knts, temperature down to - 32 deg C. Sound speed was 1438 m/sec. Propagation was upward refracting, downward reflecting (from the water's surface or the ice's under surface. 60 dB median ambient noise spectrum level (≤ 2 kHz).
TRANSIENT DESCRIPTION	Moaning sounds are either simple (tonal) or complex (pulsive) and may exhibit harmonics. They fall within the band of 25-900 Hz; they may be up to 3 sec in duration and 129-178 dB source level. Except when song sequences are being produced, moans are the most common sound. Songs resemble the trumpeting of elephants. They are in the band of 0.2-5 kHz. Each song may be up to 146 sec and composed of up to 20 repeated phrases. They are most common at 0700 and 1700 hrs. Peak source spectrum levels are 158-189 dB. Usually, only one whale in a pod will "sing" at one time. In spring ice (containing open water) songs in shallow water will be ambient noise limited at 10-15 km. Gargle-type sounds may be as high as 900 Hz, with peak energy at 400 Hz. Duration is about 1.5 sec. Source levels are 152-169 dB. Except for the phenomenon of song, yet to be described from southern right whales, there are many resemblances. Occurrence of bowhead whale sounds will always indicate that at least some open water is nearby.
DATA SOURCE	W.C. Cummings, D.V. Holliday, D.L. Ljungblad, C. Clark
SERIAL	BOW



ATLANTIC WHITESIDE PORPOISE, CLICK TRAINS, SQUEALS (AFB-50 Hz)

SUPPORTING DATA

SOURCE

STP Striped Porpoise, Stenella styx

DISTRIBUTION

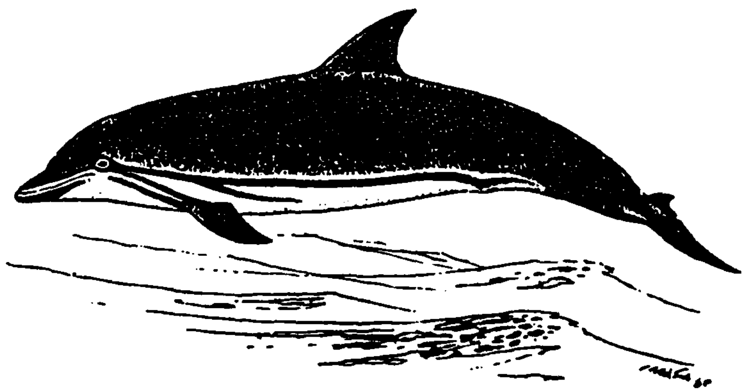
N Atlantic, S Greenland, perhaps Iceland, lower Davis Strait, Labrador Sea to Newfoundland. N Pacific, Bering Sea, Gulf of Alaska.

NUMBERS

Unknown, perhaps 1 million.

LIFE HISTORY

Size: to almost 2 m. Color: dark on dorsal (upper) surface, light undersides, dark pectoral fins, characterized by dark stripes on lower sides (2 from eye region to flippers, and a branched one from eye to anal region). Appearance: high dorsal fin. May be seen in very large schools; i.e., to 1000 or more. They stay well offshore, just avoiding ice. Food: squid and fish. May have a spring and a fall breeding season. Fearful of men and boats at sea. Longevity: to 25-30 yrs.

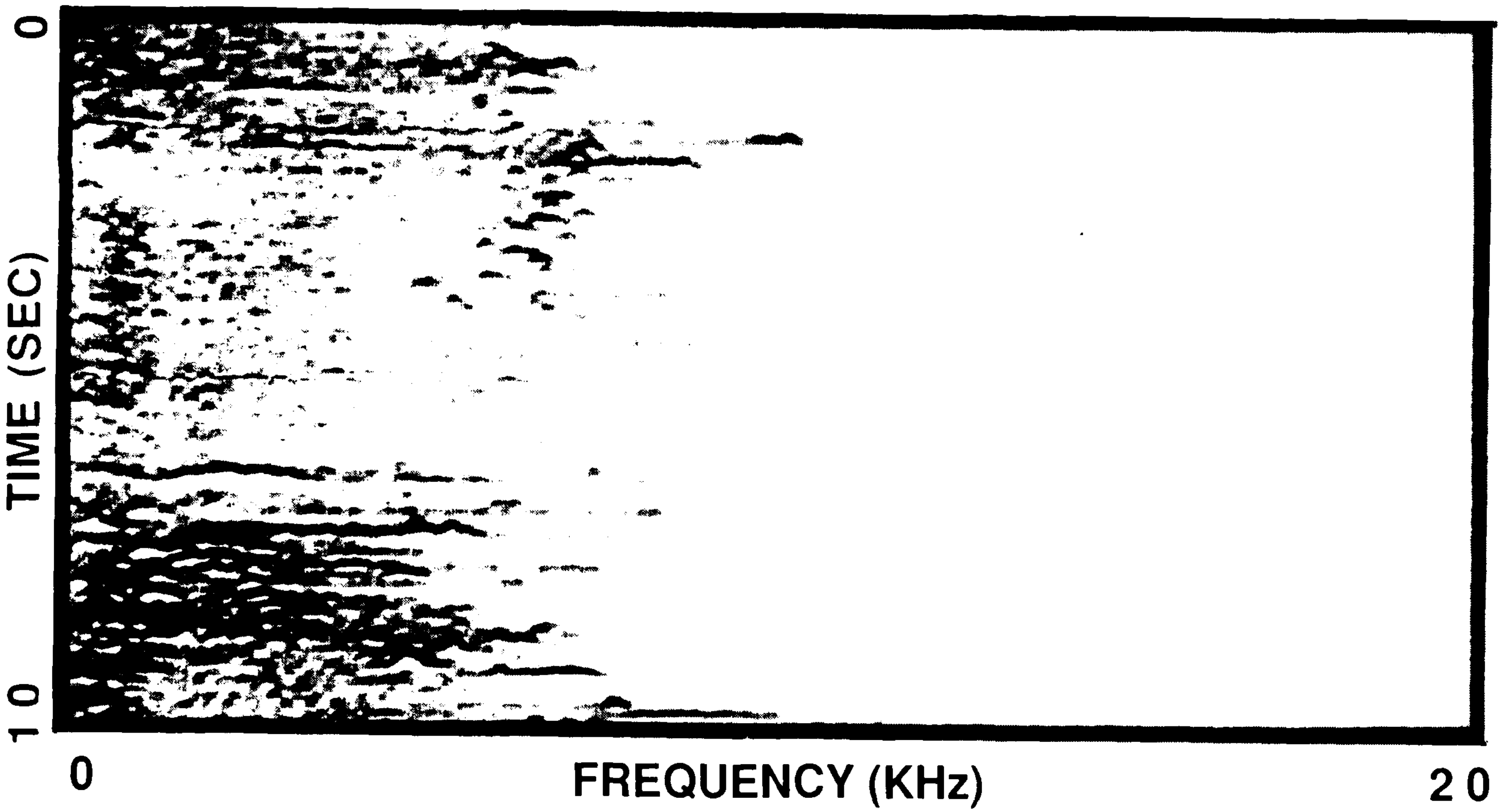


TRANSIENT OCCURRENCE

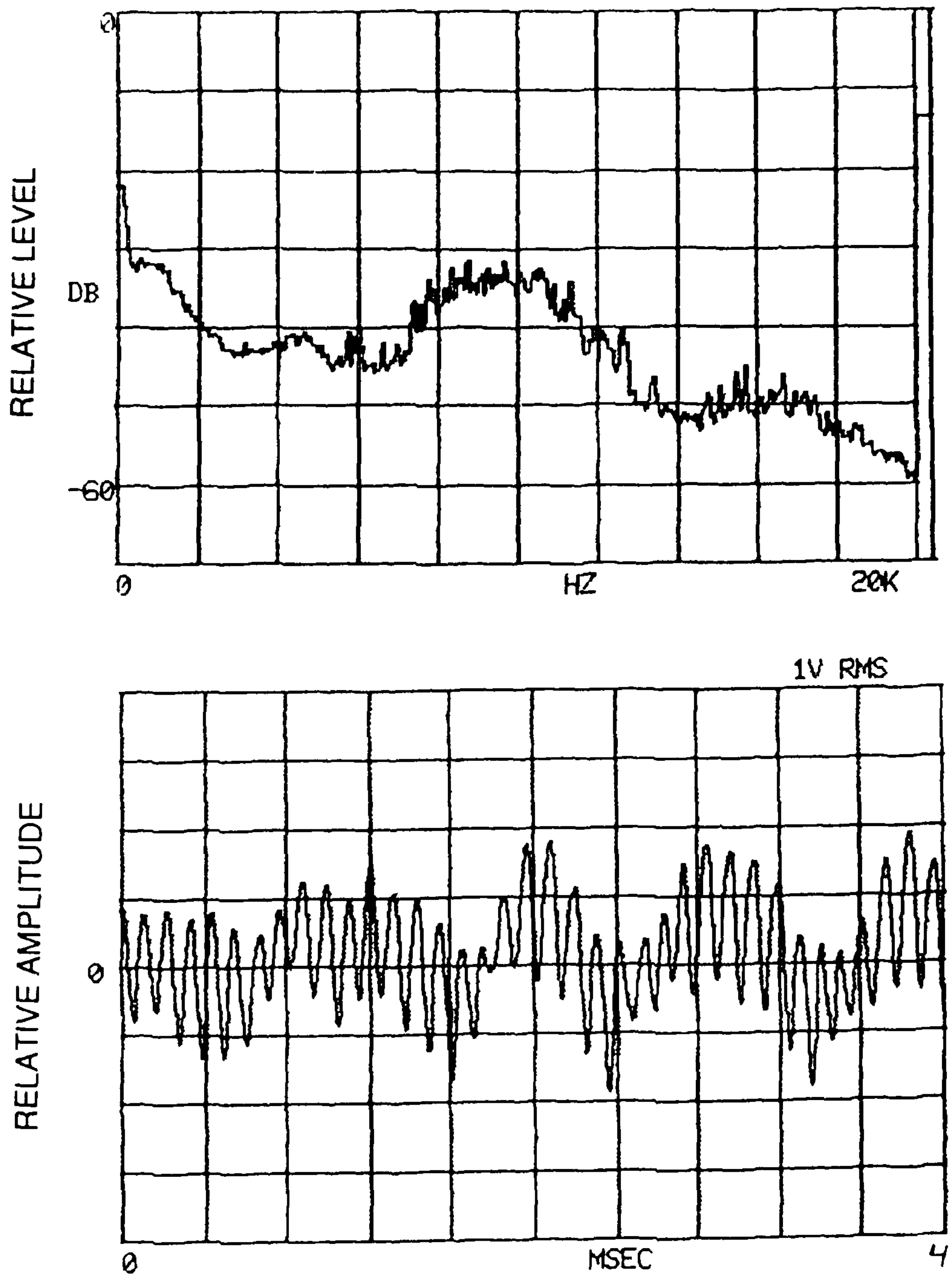
Trains of clicks, chorusing common, variable whistling.

TRANSIENT DATA

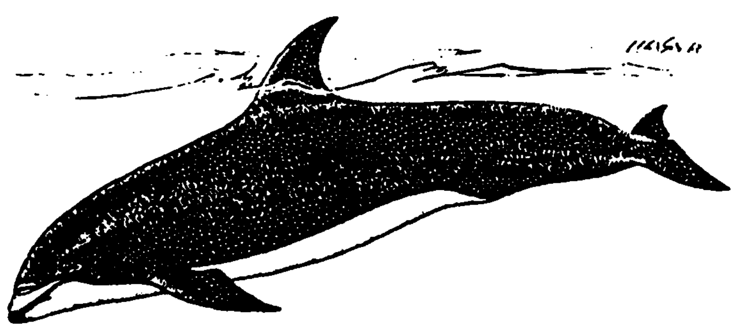
SUBJECT	**Striped Porpoise: whistles, clicks, squeals**
DATE	Unknown
LOCATION	NW Atlantic
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	This species produces trains of clicks and whistles, and much of the sound production is done in choruses from very large pods of animals. Whistles center at about 10 kHz. Clicks may be over 100 kHz. Source level has not been reported. Whistles and squeals may sweep over several thousand kHz. Clicks are very short in duration, only microseconds long. The cacophony from hundreds of animals is almost continuous.
DATA SOURCE	W. Schevill, W. Watkins
SERIAL	**STP**



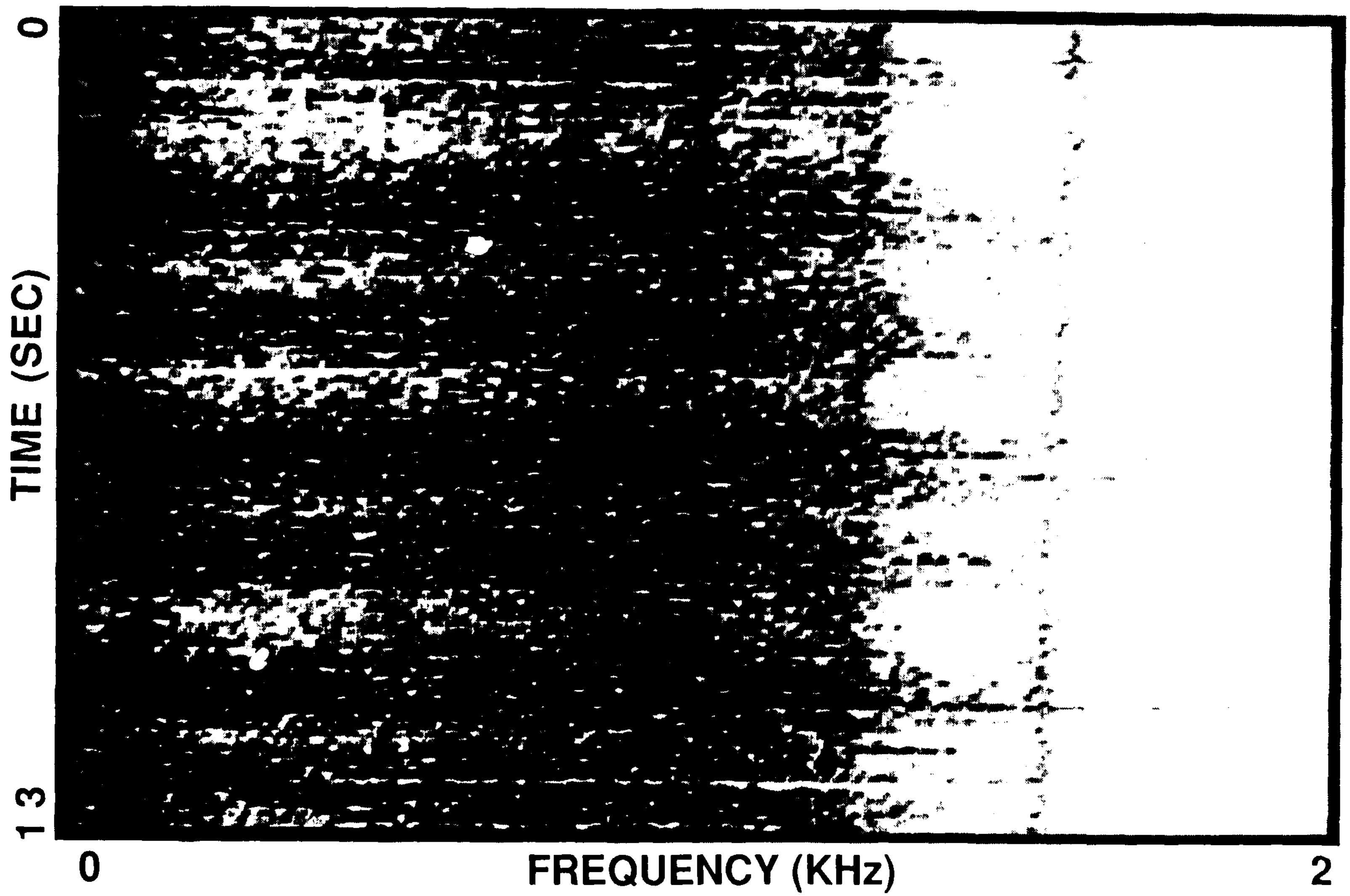
ATLANTIC WHITESIDE PORPOISE, WHISTLES, CLICK TRAINS (AFB-75 Hz)



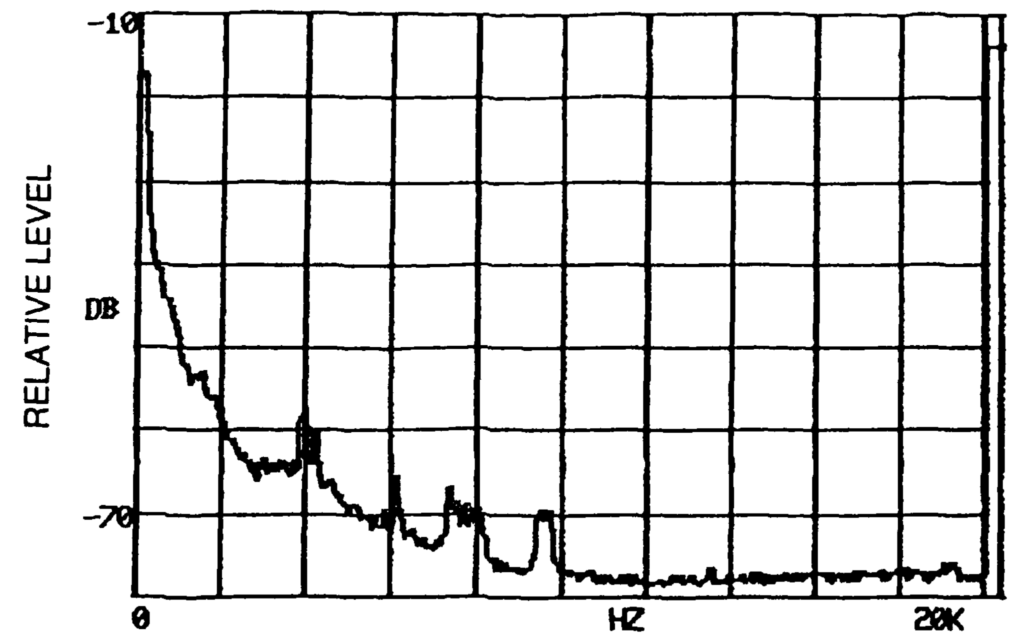
Striped porpoise, spectrum of whistle chorus (17 sec. average, above), waveform of single whistle (below). AFB 75 Hz

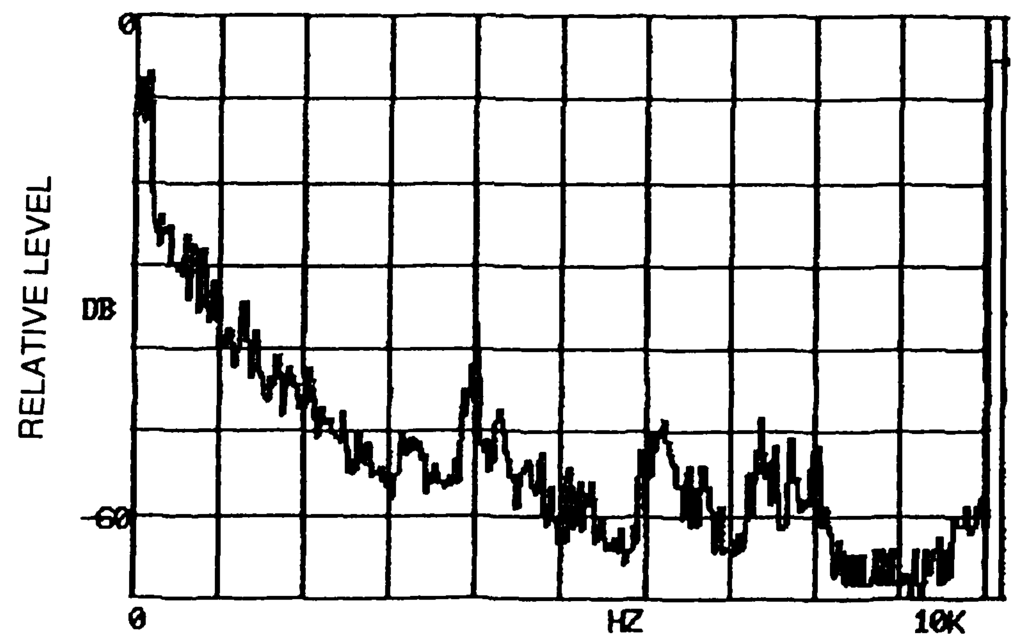
SOURCE	***WBP White-Beak Porpoise, Lagenorhynchus albirostris***
DISTRIBUTION	Only in northern N Atlantic, Newfoundland N to Davis Strait, W Greenland, Iceland, Barents and Norwegian seas and southwards. Further N than AWS.
NUMBERS	Unknown, but numerous where found.
LIFE HISTORY	Size: to 3 m. Color: black on sides and dorsal, whitish ventrally with white on underside of lower jaw. Food: fish, e.g., herring, cod, capelin; squid, crustaceans. Appears in schools of up to 1000 in E Atlantic, smaller schools in W Atlantic, offshore species. 
TRANSIENT OCCURRENCE	Whistles and squeaks, variable in occurrence.

SUBJECT	**White-Beak Porpoise: whistles, squeaks, clicks, chirps**
DATE	Unknown
LOCATION	N Atlantic
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	Whistles are 0.5-1 sec in duration over a narrow band of 6.5-15 kHz. The chirps occur at about 8-10 kHz. Clicks are very narrowband emissions. The sounds emitted by pods of up to 1000 or more individuals are nearly continuous. Source levels are not reported.
DATA SOURCE	W. Schevill, W. Watkins, H. Winn
SERIAL	**WBP**

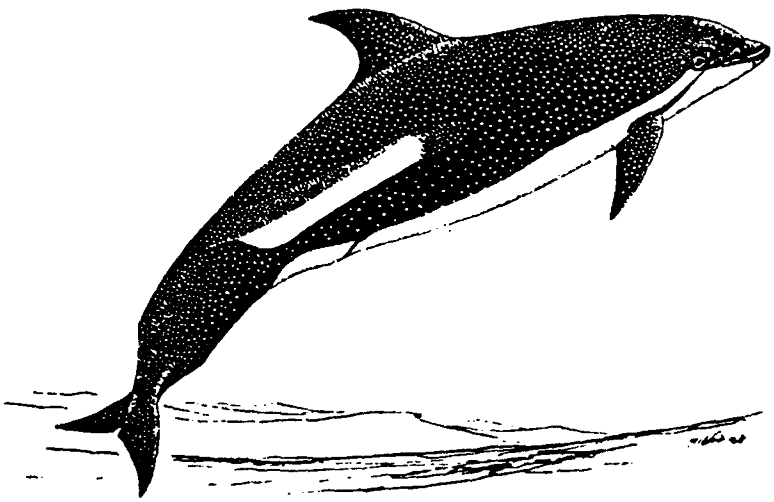


ICE, SLUSH AND BUMP (AFB-7.5 Hz)



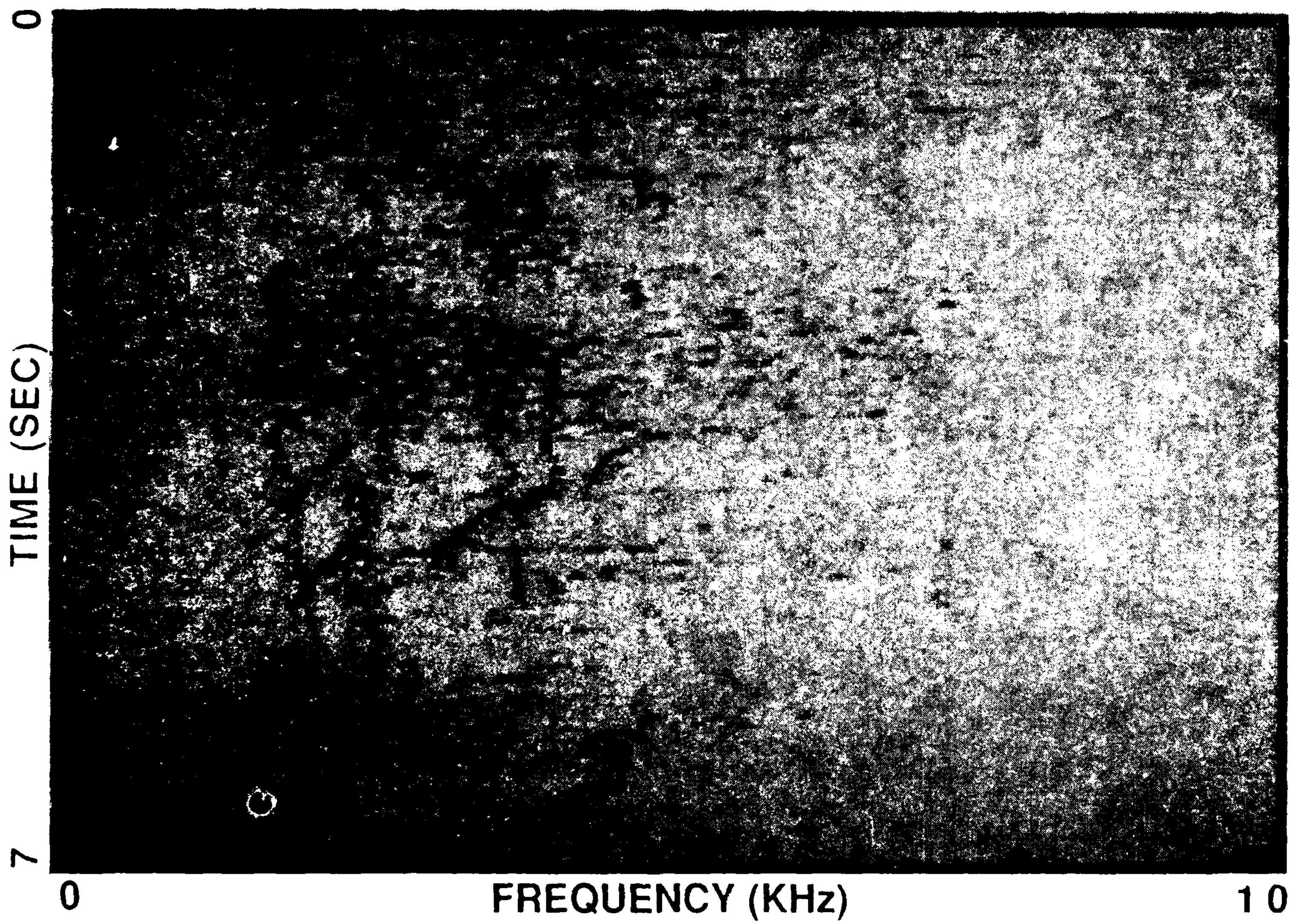


White-beak porpoise, spectrum of chirps (1.36 sec. average, above), peak hold spectrum of chirps (30 sec., below) AFB 75 Hz

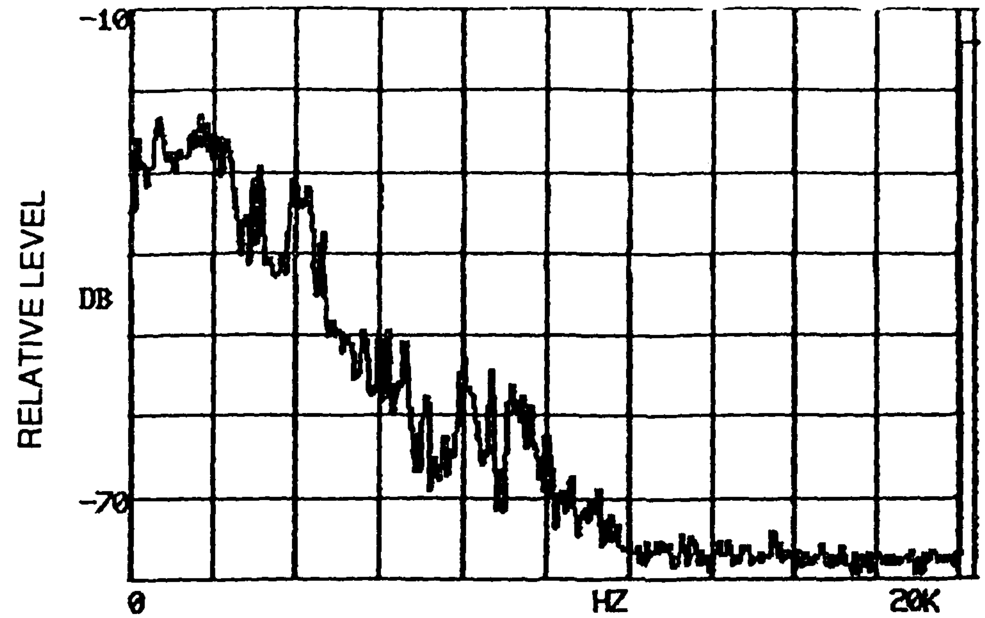
SOURCE	***WSP Whiteside Porpoise (Atl.), Lagenorhynchus acutus***
DISTRIBUTION	Only in N Atlantic, W Norway, W to possibly S Iceland, S Greenland and southward. Not as far N as Small White-Beaked Porpoise (WBP).
NUMBERS	Unknown, numerous off Newfoundland and Norway.
LIFE HISTORY	Size: to about 2.7 m. Color: black on dorsal, whitish on undersides with white side band from dorsal fin 1/2 way to flukes. Appearance: short beak, high falcate dorsal fin. Calving: young born in May-August. May occur in schools up to 1000. Food: squid, herring, migratory fishes. Many often strand on beaches. Speed in excess of 18.5 km/hr. Dive: at least 300 m. 
TRANSIENT OCCURRENCE	Variable. Clicks of high repetition rate, e.g., 200/s.

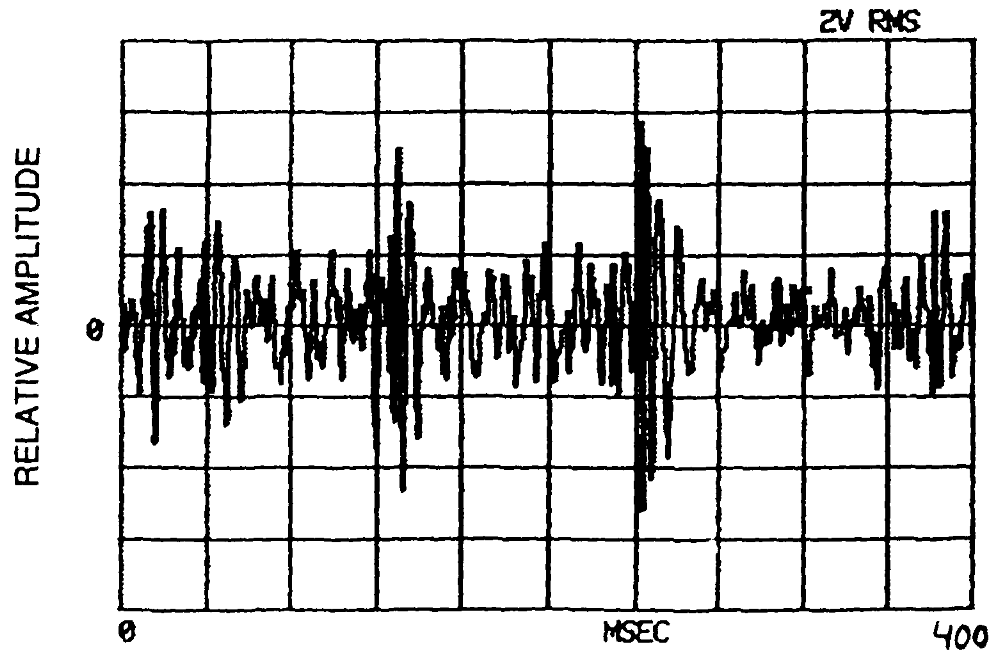
TRANSIENT DATA

SUBJECT	**Whiteside Porpoise: whistles, squeals, clicks**
DATE	Unknown
LOCATION	N Atlantic
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	Whistles and squeals vary in frequency from 1-24 kHz. Strongly modulated narrowband whistles may change frequency by 12-16 kHz over 0.5 sec. Many whistles contain several harmonics and are actually broadband clicks with energy up to 150 kHz and emitted at very high repetition rates of 80-200 clicks/sec. Clicks are only a few microseconds in duration. Other whistles are tones not composed of clicks. There are no reported source levels for the species, but a closely related species, L. obliquidens, has source levels as high as 170 dB.
DATA SOURCE	W. Schevill, H. Winn
SERIAL	**WSP**

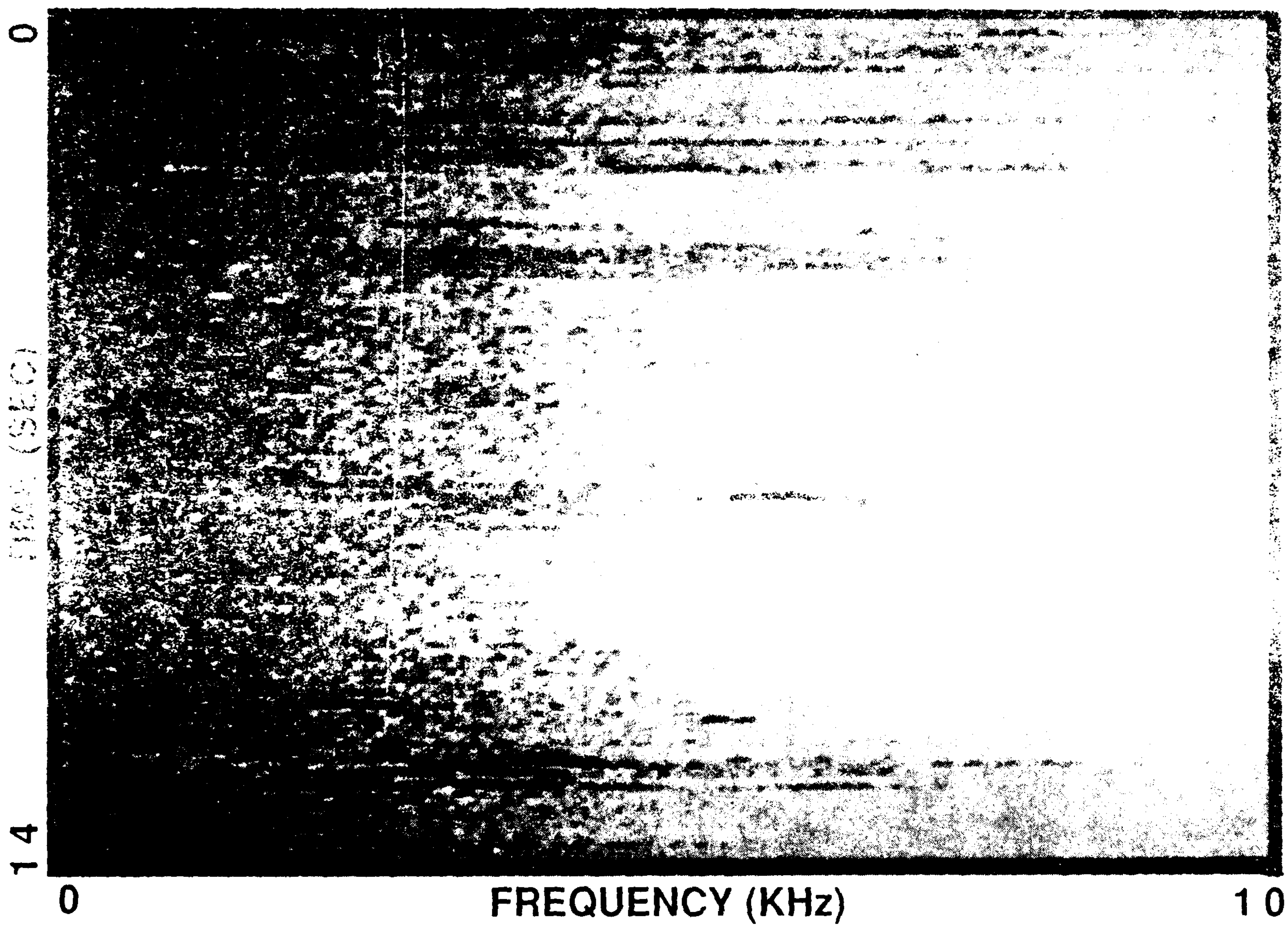


LONGFIN PILOT WHALE SQUEALS (AFB-37.5 Hz)

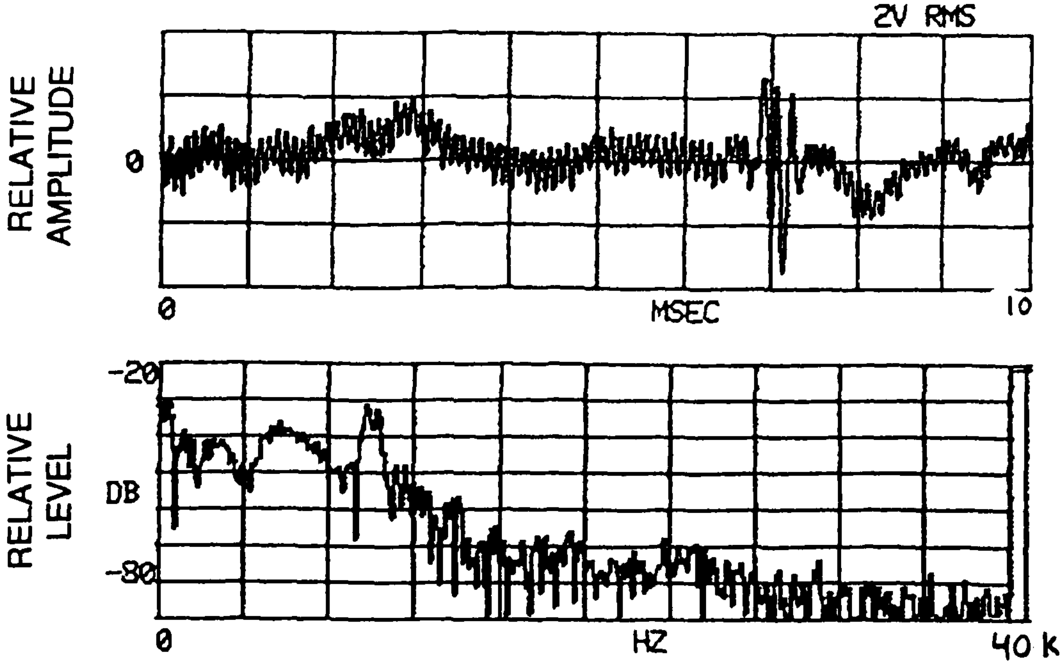


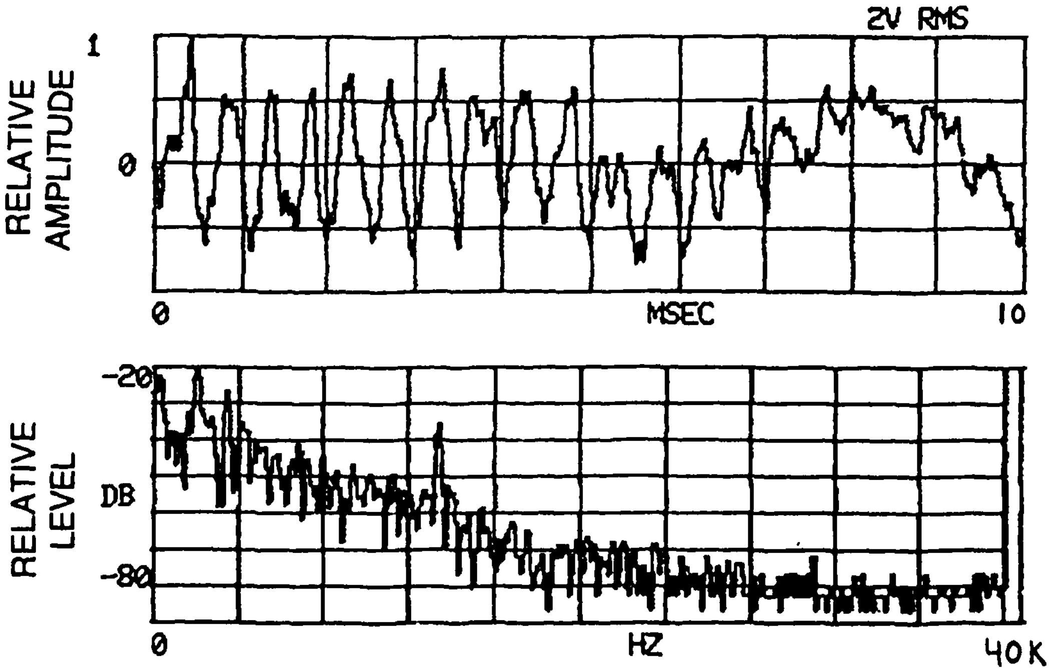


Atlantic whiteside porpoise, peak hold spectrum of click trains and squeals (32 sec., above), waveform of 5 click trains (below). AFB 75 Hz

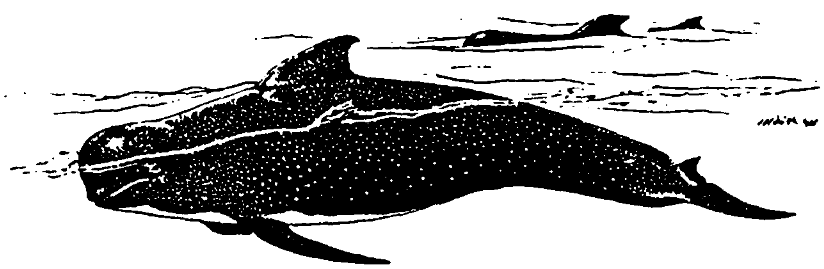


LONGFIN PILOT WHALE CLICKS, CHIRPS (AFB-37.5 Hz)



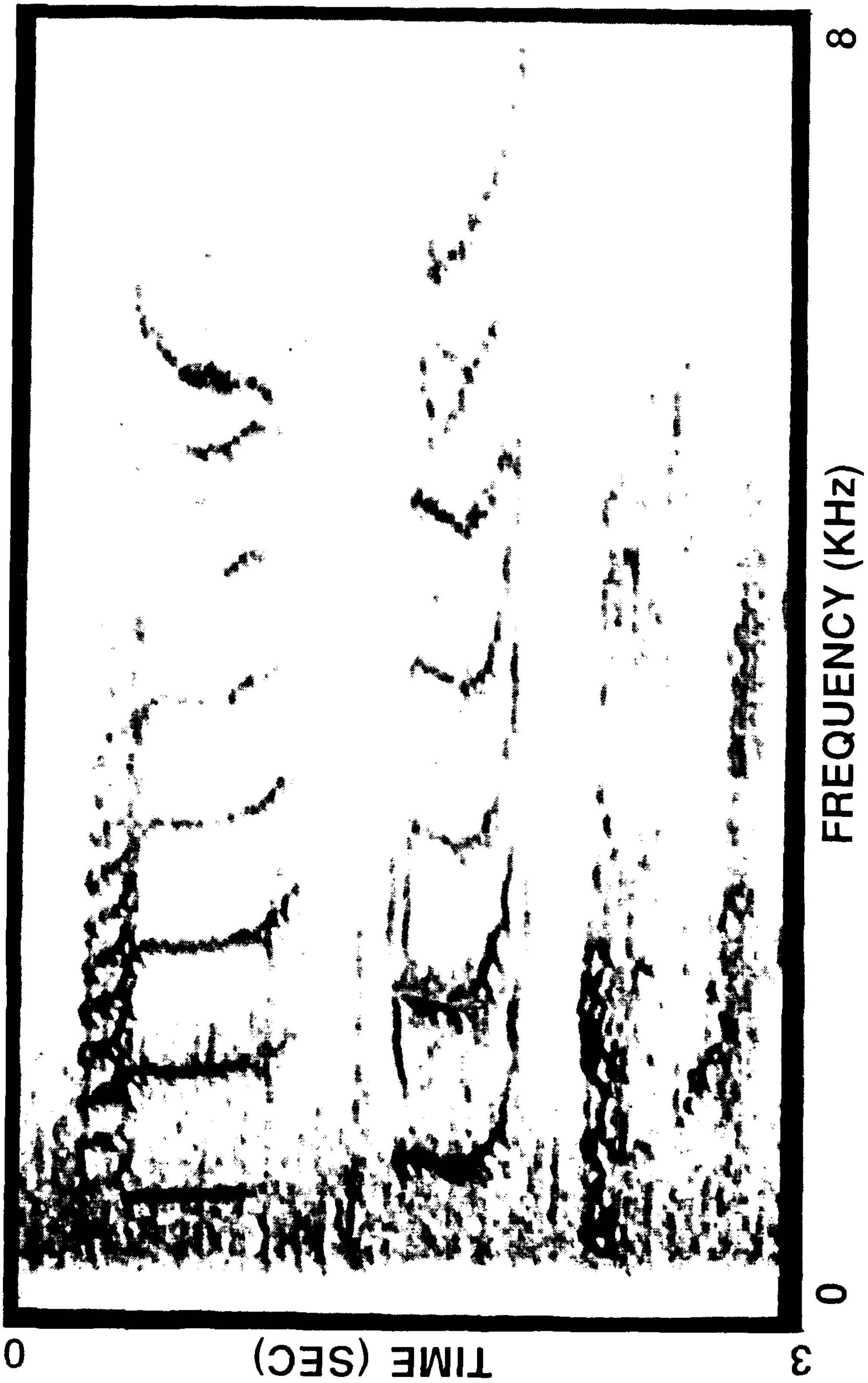


Atlantic whiteside porpoise, waveform and spectrum of whistle containing 1 click (above), waveform and spectrum of raucous squeal (below). AFB 150 Hz

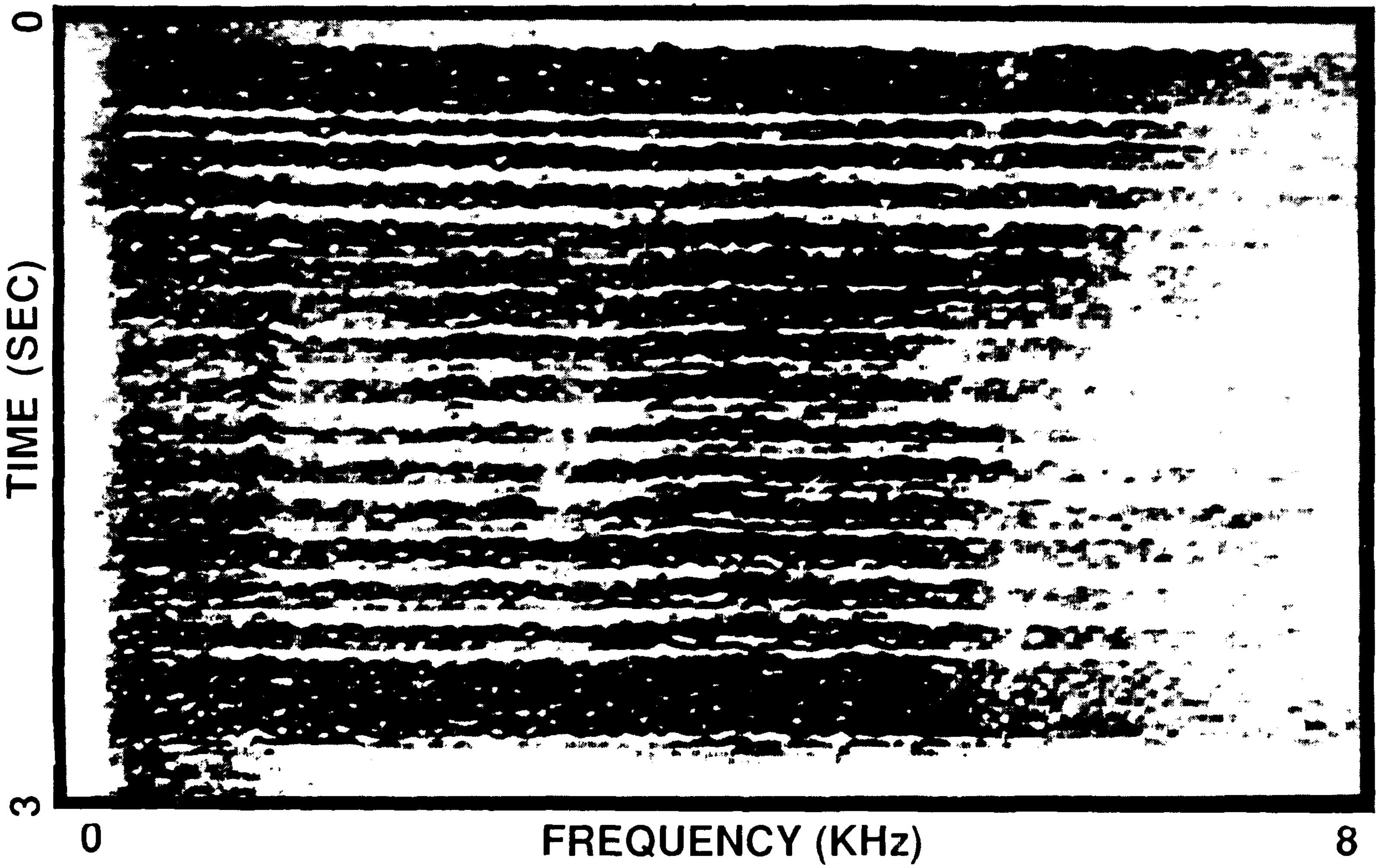
SOURCE	***PIW Longfin Pilot Whale, Globicephala melaena***
DISTRIBUTION	Cold- temperate N Atlantic, Barents Sea, off Greenland, Iceland, Norwegian Sea, E Canada, Newfoundland.
NUMBERS	Unknown,13 thousand thought to be off Newfoundland-Labrador, and 50 thousand cumulative catch figure for Newfoundland.
LIFE HISTORY	Size: to 6 m. Appearance: large bulbous head, thick tail stock, long dorsal fin. Color: almost all black. Calving: one about every 2-3 yrs after a pregnancy of 16 mo. Longevity: to 20 yrs. Food: mostly squid; fish, e.g., turbot, mackerel, flounder. Occurs in schools of up to 100s. May easily be driven ashore. May beach and die in large groups. Can swim 5-8 km/hr. Dive: to 600 m. Called "pilot" whale because N Sea fisherman were guided to schools of herring by the whale's presence. Also known as potheads or blackfish. 
TRANSIENT OCCURRENCE	Pods produce sounds almost continuously. No particular periodicity noted.

TRANSIENT DATA

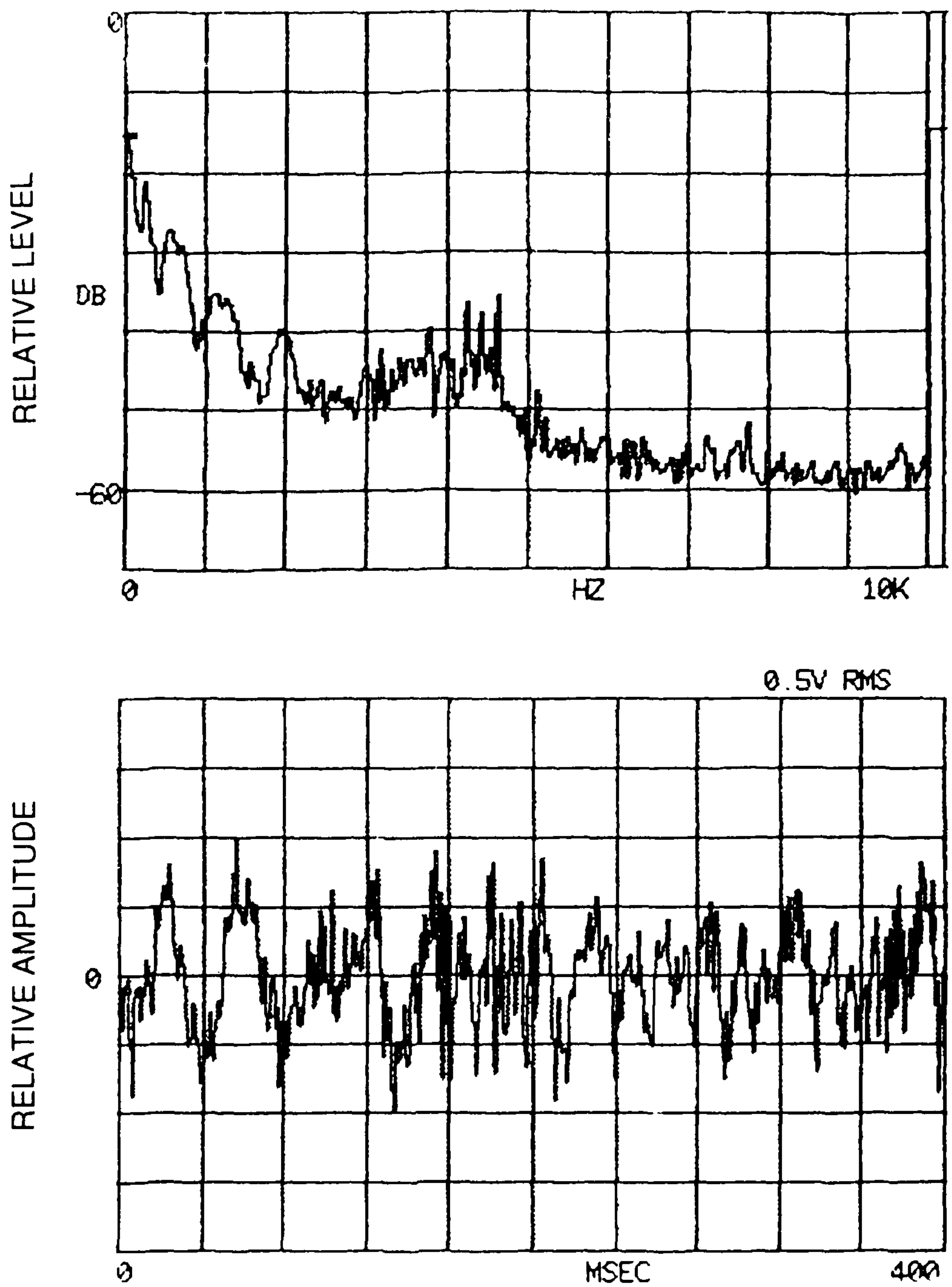
SUBJECT	**Longfin Pilot Whale: squeals, whistles, clicks**
DATE	July, year unknown
LOCATION	Trinity Bay, Newfoundland
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	The sounds of both species of pilot whales (including shortfin, found in warmer waters around the world) are very similar. Squeals are narrowband (to 500 Hz) raucous whistles that are swept upward or downward by as much as 10 kHz. They may even have a pulsed characterization. Whistles are narrowband (to about 50 Hz) almost pure tone, frequency modulated, protracted sounds. Both squeals and whistles may be several seconds in duration. Two whistles may be produced at the same time such that, frequency-wise, they may cross one another. The clicks are broadband, with upper frequencies as high as 40 kHz. They may be produced at the same time as whistles or squeals, by a single animal. Click trains may be several seconds in duration at a repetition rate of 10-1000 clicks/sec. Maximum overall source level of pilot whale sounds is 180 dB. It has been suggested that there is enough intraspecific variation between the calls of pilot whales to identify individual animals. Since longfin pilot whales are very gregarious and occur in large pods, high-level choruses of these sounds are the usual form of occurrence.
DATA SOURCE	W.E. Schevill, W.A. Watkins, W.W. Steiner, H.E. Winn, R.G. Busnel, W.C. Cummings
SERIAL	PIW



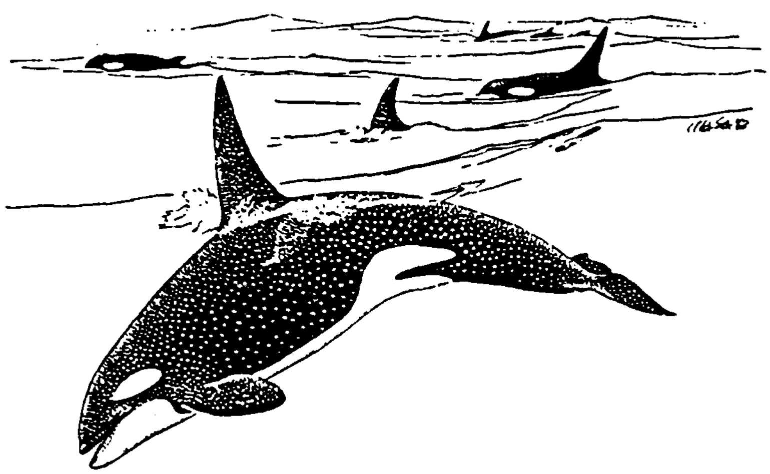
KILLER WHALE COMPLEX SCREAM (AFB-30 Hz)



KILLER WHALE CHATTER (AFB-30 Hz)

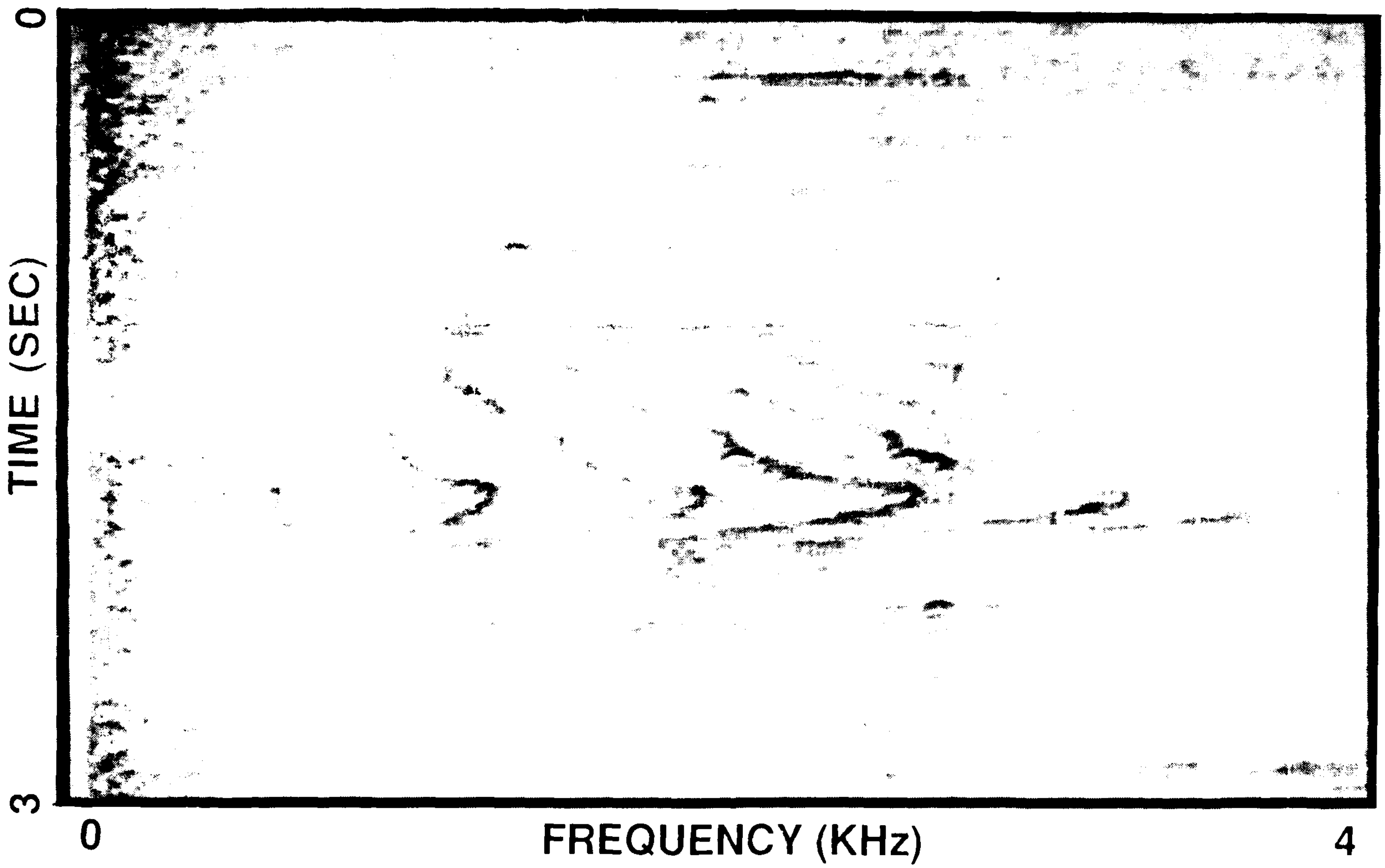


Longfin pilot whale, peak hold spectrum of clicks and squeals (10 sec., above), waveform of raucous scream (below).
AFB 37.5 Hz

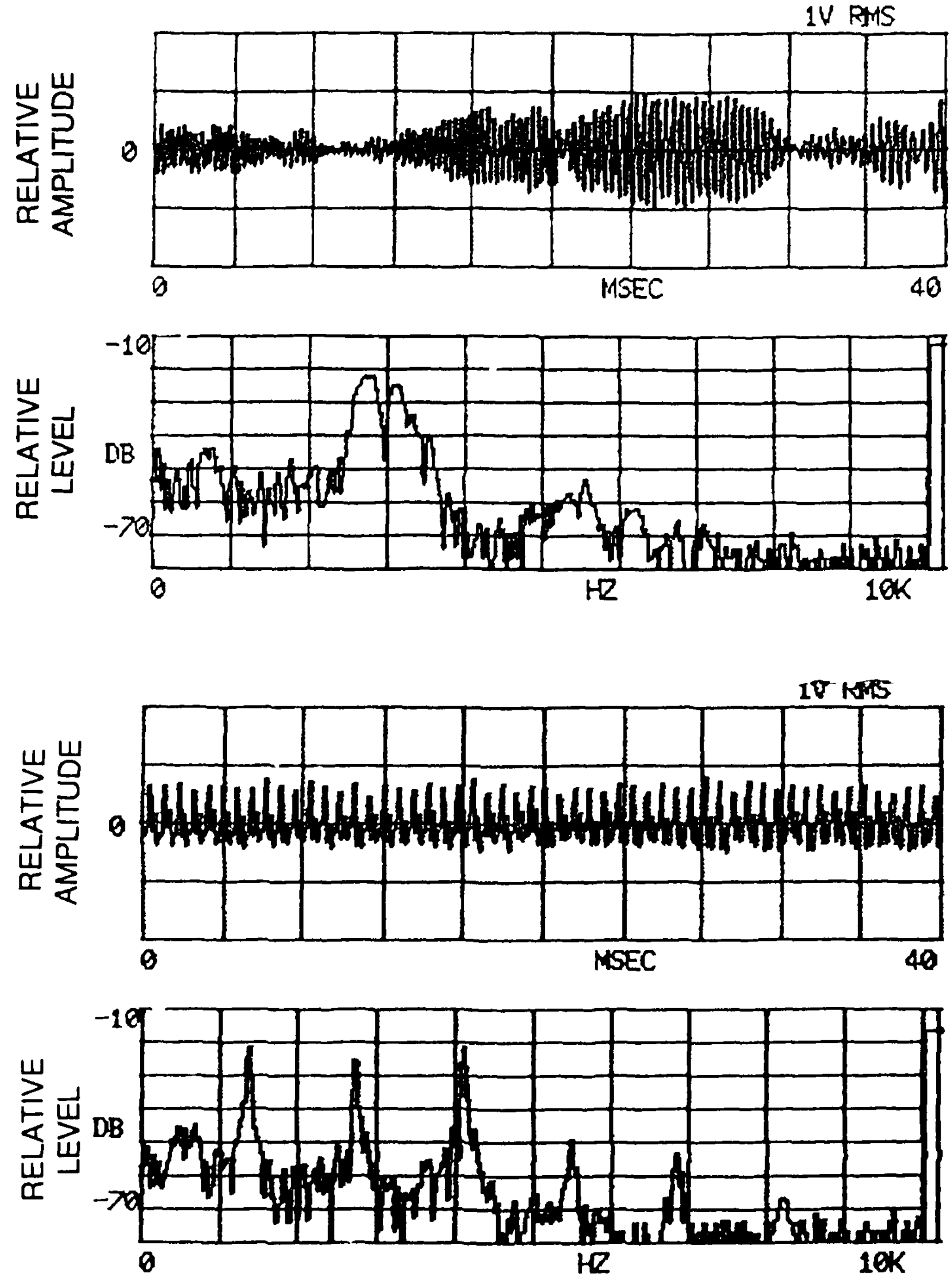
SOURCE	***KIW Killer Whale, Orcinus orca***
DISTRIBUTION	N Atlantic: to Greenland, Iceland, White and Barents seas, Novaya Zemlya. N Pacific: SE AK, Aleutians, Bering, Chukchi, Beaufort seas, E Kuriles, Okhotsk. Moves S-N with marginal ice changes.
NUMBERS	Little data. About 3000 off Prince William Sound, AK, Shalikov Strait, to the S. Over 1100 off Norway; 300, Iceland; 300, British Columbia.
LIFE HISTORY	Size: to 10 m, females, smaller. Appearance: sleek, males with high dorsal fin (to 2 m), contrasting whitish patches near eye, saddle, and sides-belly. Gestation: 12 mo. Longevity: 25-30 yrs. Predation: hunts fiercely in groups (pods) on fish, birds, marine mammals, squid. Known to attack large whales, e.g., blue whales to 30 m. Very social with other members of the same species. Trains easily, used in oceanarium displays. Often found close to and within broken ice. Known to become trapped in ice fields. 
TRANSIENT OCCURRENCE	Sound production almost continuous. Most sounds are click structured of variable repetition rate.

TRANSIENT DATA

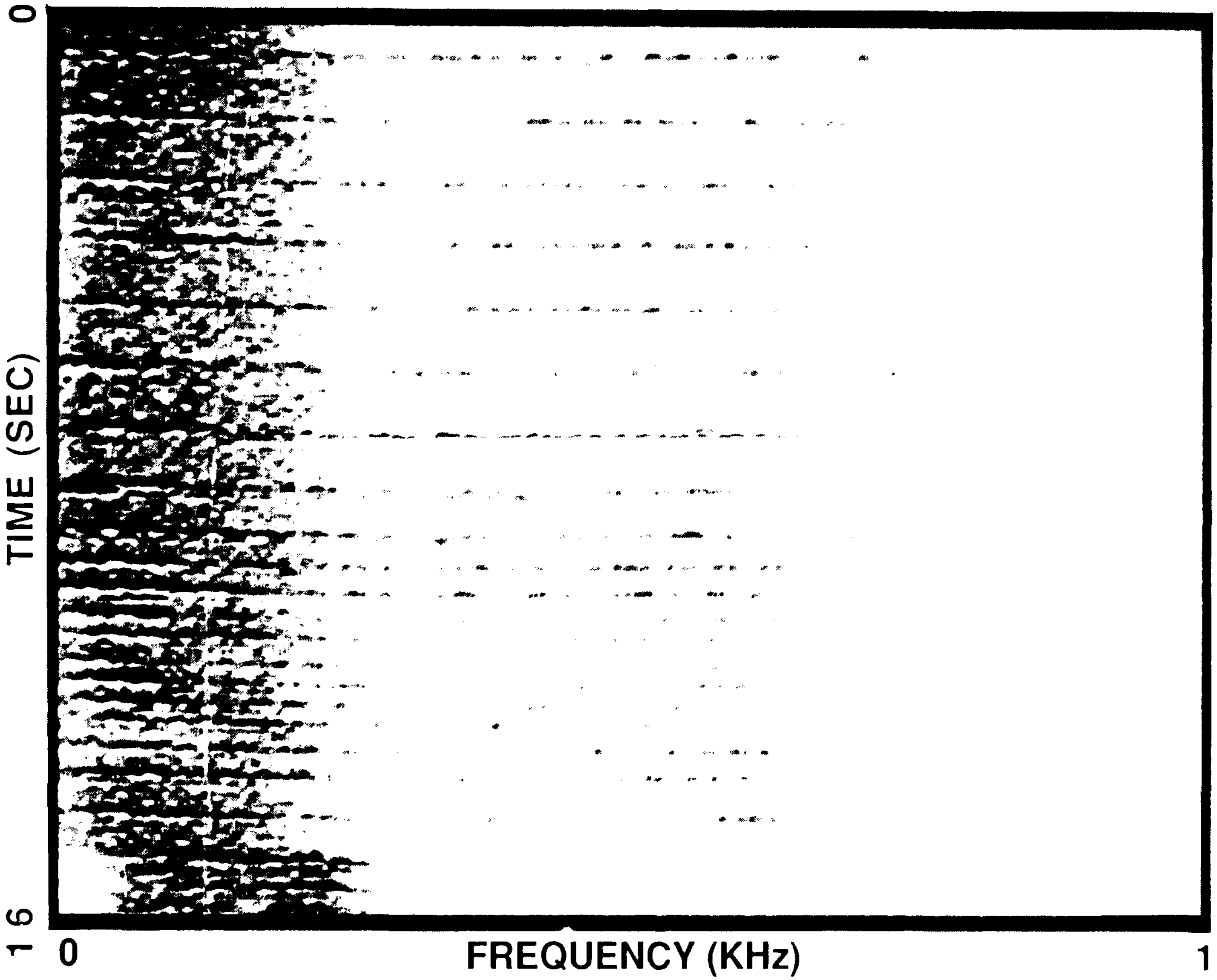
SUBJECT	**Killer Whale: clicks, screams, whistles**
DATE	1971
LOCATION	Embayment, state of Washington
CONDITIONS	Calm water surface, day and night recordings
TRANSIENT DESCRIPTION	Principle energy of clicks may vary from 10-30 kHz, but lowest frequencies may extend down to about 100 Hz. Duration may be 0.8-25 msec, and repetition rate may be as high as 350/sec. Clicks are usually produced in short bursts of < 20. Source level is up to 180 dB. The most common sounds are screams with upward, downward (or combinations thereof) amplitude modulation that may sound like frequency modulation. Basically, screams are composed of time-varying pulses of relatively narrowband content. Screams are found in the band from about 500-28 kHz, with pulse repetition rates of up to 5000/sec. Duration of screams are 0.1-5 sec. Maximum source levels are > 178 dB, peak. Whistles are not very common and are nearly pure tones ranging in frequency within the band of about 0.5 to 18 kHz. They may be protracted in duration to about 10 sec. Source levels are unknown. Rarely does one encounter killer sounds from only one individual. They are normally heard as groups, because the animals are usually in small pods with frequent vocal activity.
DATA SOURCE	P. Spong, W.C. Cummings, M. Dahlheim, J. Ford, H. Dean Fisher, others
SERIAL	KIW



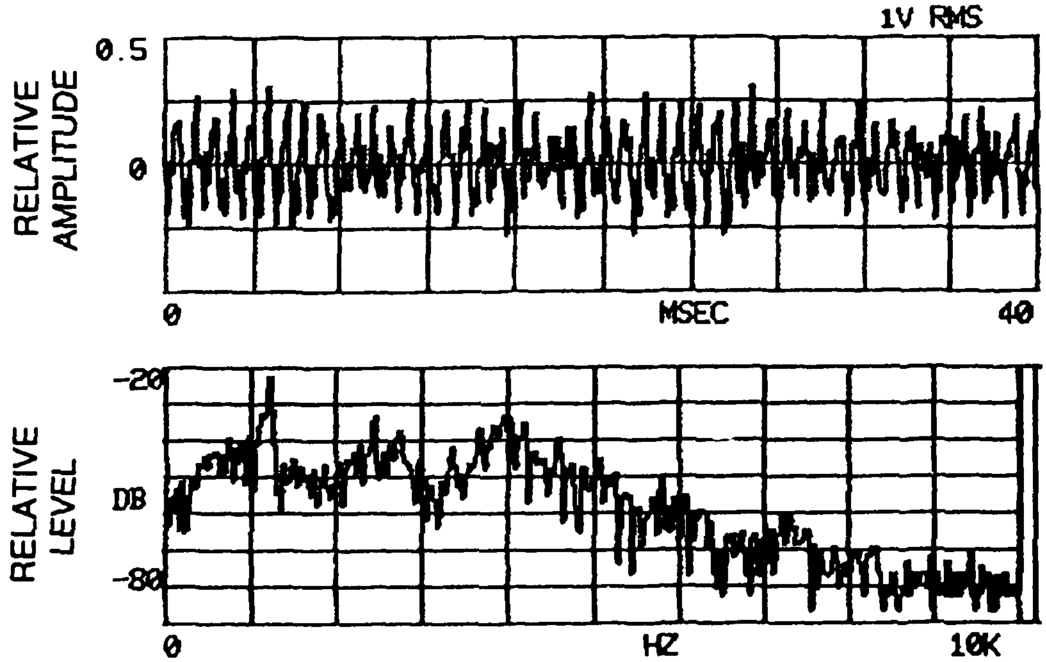
HARBOR (COMMON) PORPOISE. CLICKS. SQUEALS (AFB-15 Hz)



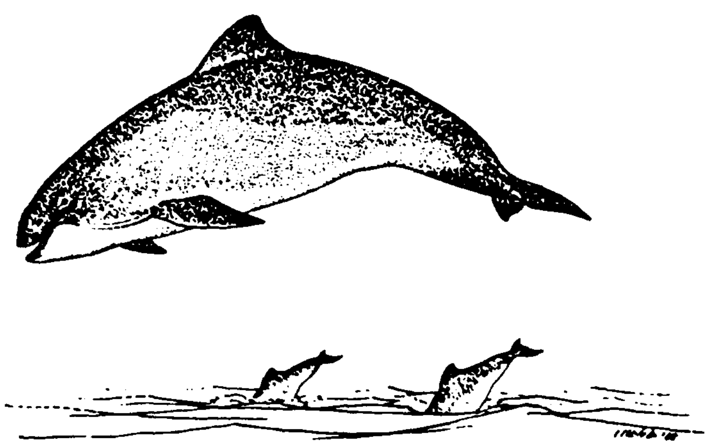
Killer whale in northern waters, waveform and spectrum of main section of 3-part scream (above), waveform and spectrum of main section of upscream (below). AFB 37.5 Hz



SPERM WHALE CLICK TRAIN (AFB-3.75 Hz)

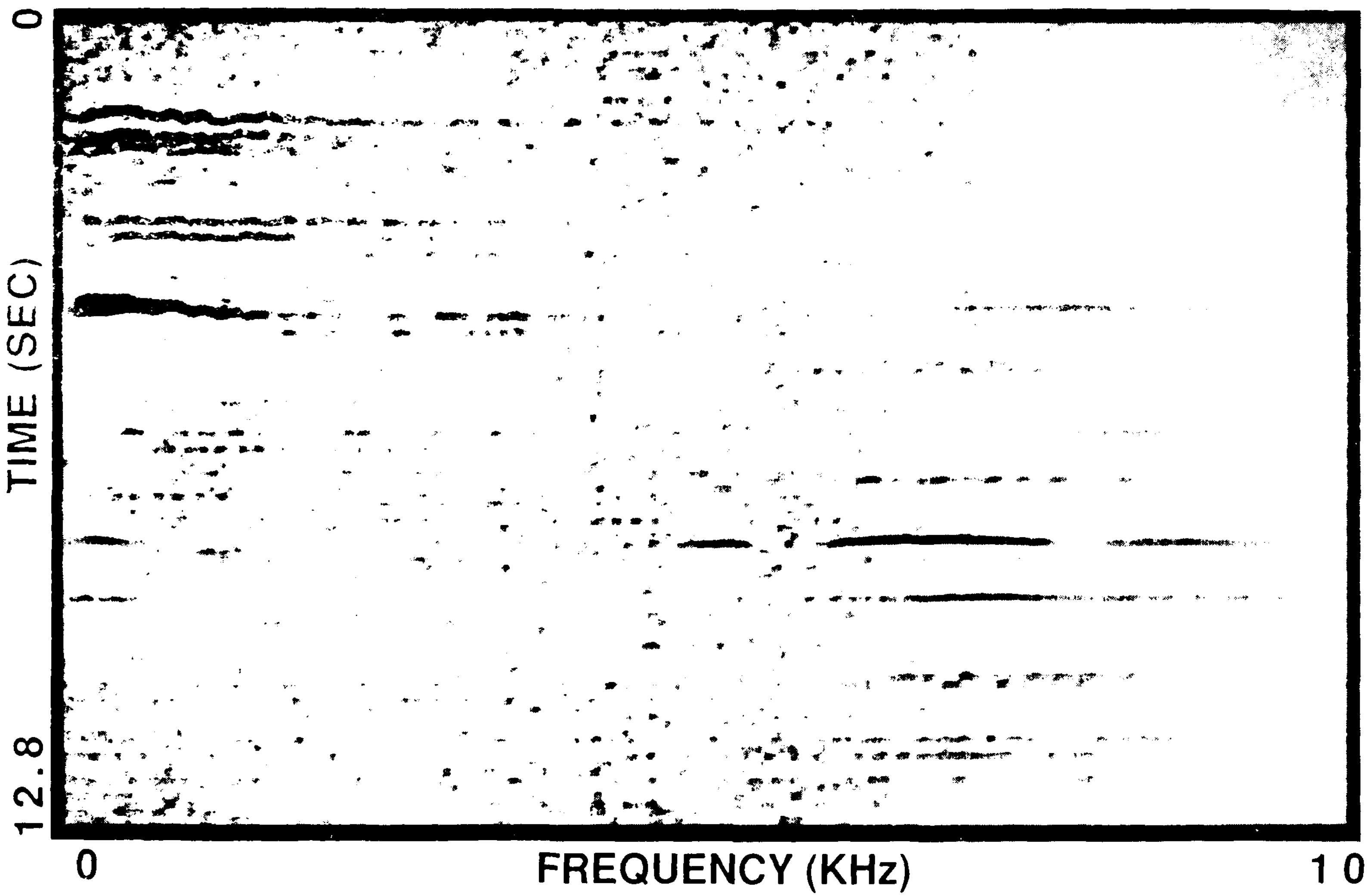


Killer whale in northern waters, waveform of chatter (above), spectrum of same (below). AFB 37.5 Hz

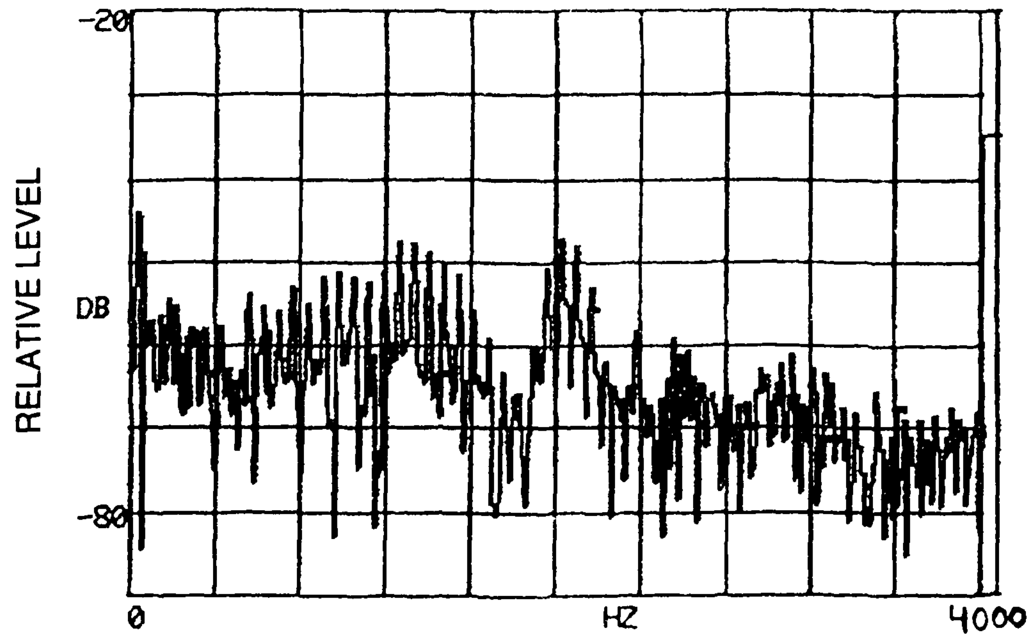
SOURCE	***HAP Harbor or Common Porpoise, Phocoena phocoena***
DISTRIBUTION	N Atlantic: Lower Baffin Island, Davis Strait, Iceland, Norwegian and White seas, British Isles, westward. N Pacific: Pt Barrow S to Chukchi and Bering seas, Gulf of Alaska southward.
NUMBERS	Unknown, but certainly over 100 thousand,10-15 thousand for W Greenland, alone.
LIFE HISTORY	Size: to 1.8 m (50 kg), females slightly smaller. Color: upper surface gray, sides lighter gray, undersides whitish. Food: crustaceans, squid, flounders, herring, cod, haddock. Timid, often occurring in large groups of hundreds. Slow swimming speed. Coastal or near ice for most part of range. 
TRANSIENT OCCURRENCE	Variable in occurrence, to 1000 clicks/sec, trains.

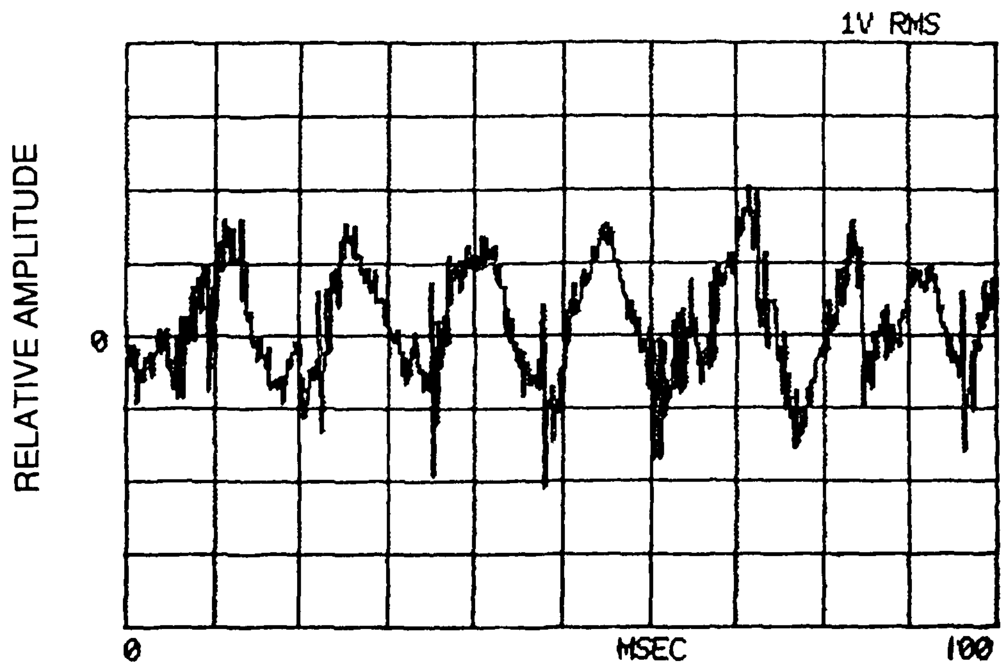
TRANSIENT DATA

SUBJECT	**Harbor or Common Porpoise: clicks and click trains**
DATE	September 1965
LOCATION	Passamaquoddy Bay, Gulf of Maine; New York Aquarium, Western Baltic
CONDITIONS	Animals held in fish weir, 9-10.6m water, mud bottom (Gulf). Noisy aquarium tanks (N.Y.).
TRANSIENT DESCRIPTION	This porpoise produces very faint clicks as low-frequency narrowband pulses, mostly near 2 kHz, 2-3 kHz. Pulses were 0.5-5 ms in duration with entire pulse trains to 2 sec. Repetition rates may be up to 1000/sec. Clicks may have frequency components to 250 kHz. They may appear singly, with a dominant single frequency. Overall scurce level is about 101 dB for low-frequency clicks and 132-149 dB for the high-frequency clicks. Other sounds, such as whistles and squeals that are normally recorded from delphinid porpoises, are rarely heard. When they do occur, they are a manifestation of the repetition rate and the accompanying harmonics to 8 kHz. Since this species is extremely common where found, it would seem that more bioacoustics investigation is called for.
DATA SOURCE	C. Ray, R.G. Busnel, H. Winn, B. Mohl
SERIAL	**HAP**



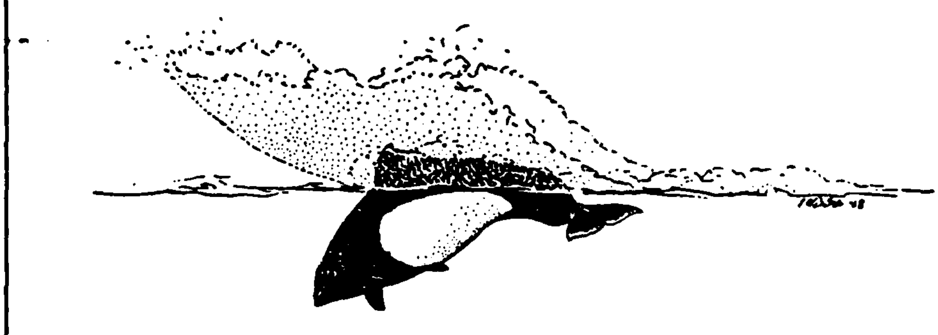
ICE STRESS CRACKS (AFB 37.5 Hz)





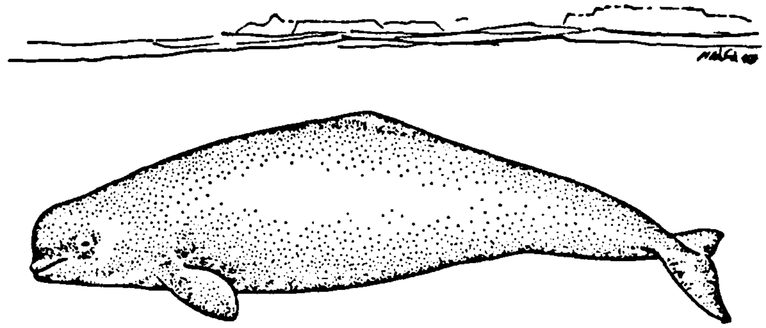
Harbor or common porpoise, spectrum of click train (above), waveform of same (below). AFB 15 Hz

SOURCE	***DAP Dall's Porpoise, Phocoenoides dalli***
DISTRIBUTION	Only N Pacific. Gulf of Alaska (including SE), S Bering and S Okhotsk seas.
NUMBERS	Unknown, probably 2.5-3 million.
LIFE HISTORY	Size: to 2 m (150 kg), males are larger than females. Appearance: very heavy body (for length), small flippers. Color: blackish with a white under saddle reaching to above midline. Food: squid, fish. Usually occurs in small groups, but sometimes seen in schools up to 1000. Swims very fast, erratic, frequent surfacing and breaching. Hunts in groups.
TRANSIENT OCCURRENCE	Random click trains. Sounds not as common as with most other porpoises.



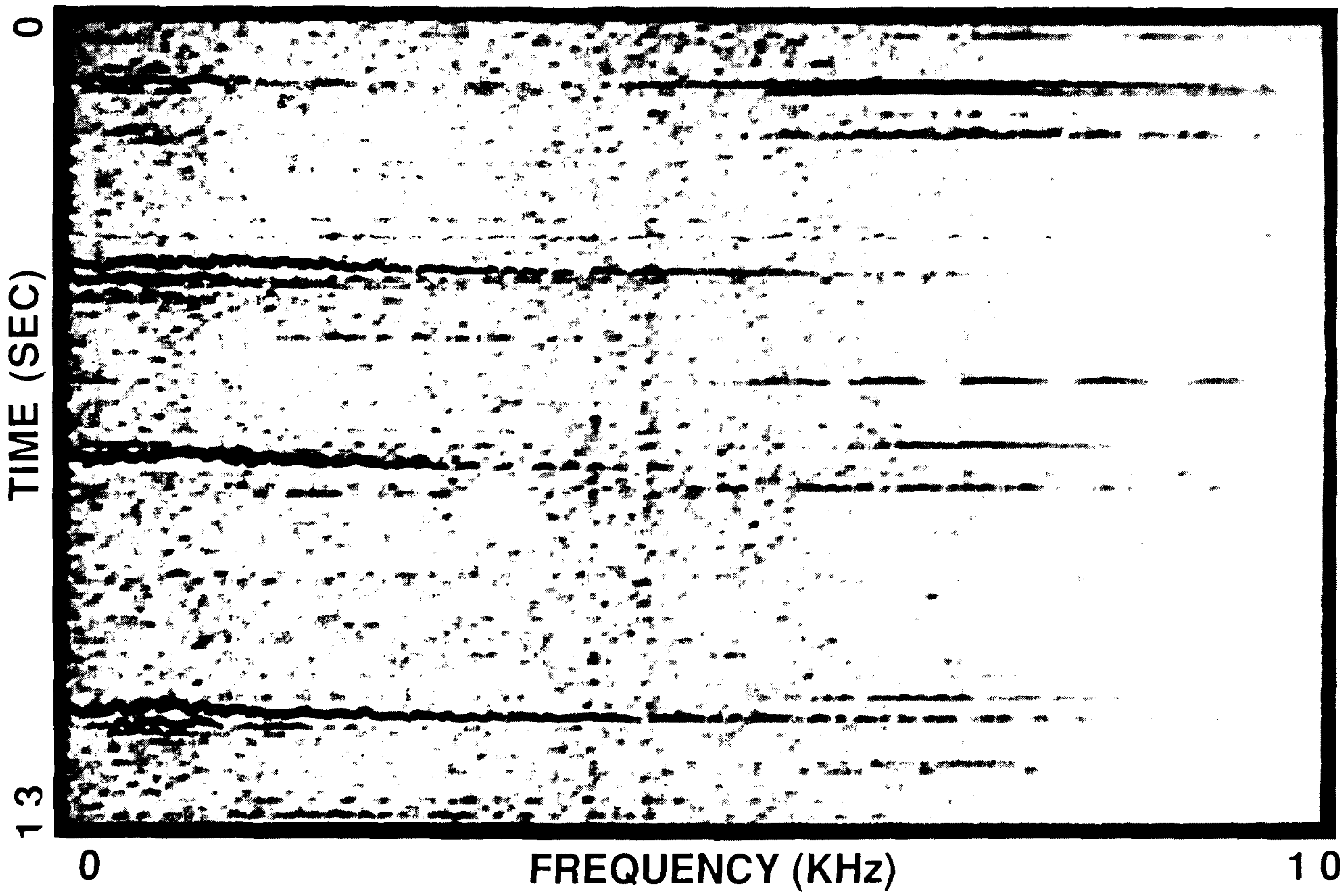
TRANSIENT DATA

SUBJECT	**Dall's Porpoise: click trains (low frequency), click series as apparent whistles or squeals**
DATE	Unknown
LOCATION	Unknown
CONDITIONS	Unknown
TRANSIENT DESCRIPTION	Click duration is 0.5-5 ms. Individual click frequency may be very low (to 40 Hz) and available information indicates that the limit may be 15-20 kHz, although there is some question about the upper limits of the recording equipment. Click repetition rate may be from 15-1000/sec. The amplitude modulation is so well controlled that whistle- or squeal-like sounds are produced, primarily as a function of rapid changes in the repetition rate.
DATA SOURCE	W.E. Evans, W.E. Schevill, W.A. Watkins, B. Mohl, F. Awbrey, A. Bowles (suitable tape recordings unavailable for analysis)
SERIAL	**DAP**

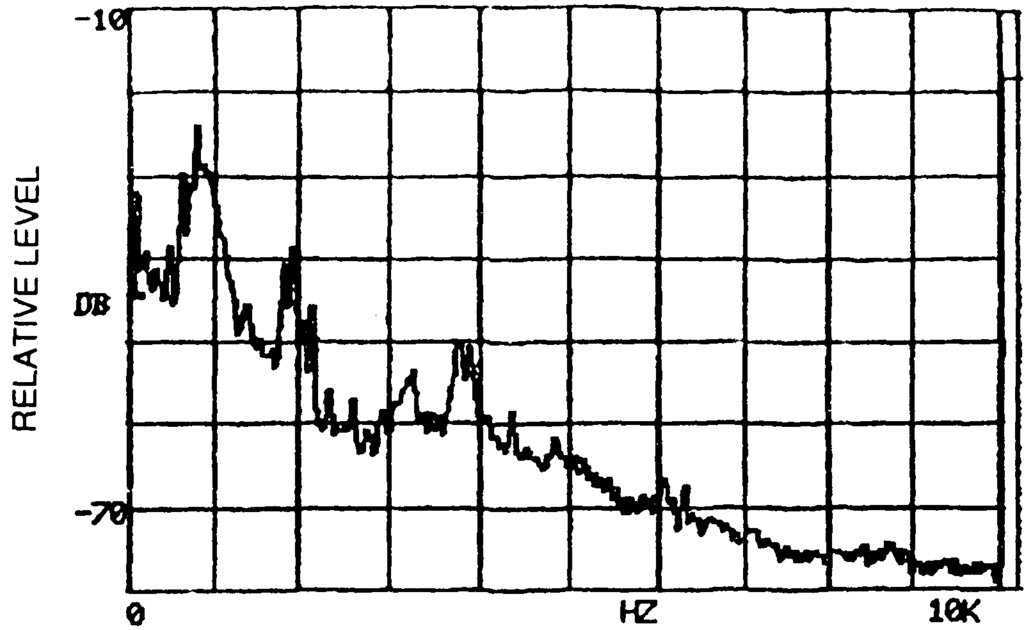
SOURCE	***BEW Beluga or White Whale, Delphinapterus leucas***
DISTRIBUTION	N Atlantic: widespread to SE Greenland, including Barents, White, Baltic seas. N Pacific: AK, Okhotsk, Bering, Chukchi, Beaufort seas, as far S as Japan. May be found in heavy ice floes, but migrates far to avoid heavy solid ice. Truly Arctic.
NUMBERS	In huge herds of up to thousands. Worldwide population is unknown, but off N America, one survey yielded 35 thousand, of which 26 were off Canada.
LIFE HISTORY	Size: to 5 m. Appearance: no dorsal fin, head is round and blunt with a short snout. Color: almost uniformly yellowish or grayish white, young are bluish black or mottled. Difficult to confuse this species with any other on the basis of appearance. Longevity: 25-30 yrs. Food: small fish, e.g., salmon smolts, herring, halibut, flounder; squid, crabs. Concentrates in large groups for feeding and calving (summer). Ice governs activities in certain areas and seasons. Easily disturbed by man's presence and man-made noise, and recognizes the potential threat evidenced by killer whale sounds. Sometimes attracted to quiet vessels. 
TRANSIENT OCCURRENCE	Clicks with repetition rate of 5 ms, in trains to 30 sec. Chorusing is common, in cycles. Vocalization is very common.

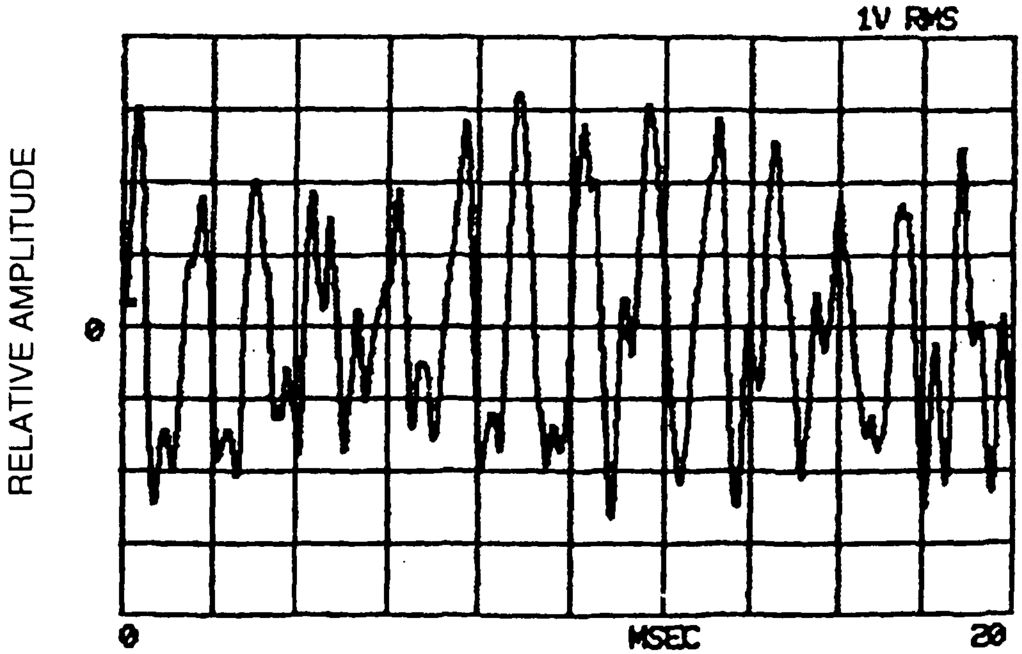
TRANSIENT DATA

SUBJECT	**Beluga or White Whale: clicks, squeals, whistles, chirps, yelps**
DATE	May-June 1980, September 1981, April-May 1982
LOCATION	MIZ, off Pt Barrow, Prudhoe Bay region, edge of main ice pack
CONDITIONS	Calm sea, wind 0-15 kn, spring leads, broken ice margin, newly forming ice in summer-fall lead
TRANSIENT DESCRIPTION	Belugas are rarely encountered as single animals. The species is so well known for sound production that it was dubbed "sea canary" by early seafarers. Sounds are usually produced in choruses. Whistles, high-frequency click trains, and squeals are common. FM whistles are up or downswept over 0.5-2 sec. Most energy is in the band from 1-10 kHz. Some whistles are AM with the most energy from 2-5 kHz including several sideband frequencies. The most common sounds are short (50-150 ms) yelps that often appear in trains of 4-5 in number. Yelps are in the region from 1-3 kHz with as many as 10 harmonics up to 13 kHz. The species is known to echolocate, perhaps better than that of the bottlenose dolphin (Tursiops truncatus) at a maximum of 10 dB more noise. Click trains may last up to 30 sec, with repetition rates from 15-210 pulses/sec, normally 20-60. Most energy of clicks is in the region of 12-30 kHz. The animal is very much accustomed to heavy ice cover. Along with the narwhal, belugas are perhaps the most adapted odontocete whale for moving through heavy broken ice. Individual source levels are 145-155 dB, perhaps to 175. Source levels of herds may be 160 to 175 dB, overall.
DATA SOURCE	W.C. Cummings, D.V. Holliday, many others
SERIAL	**BEW**

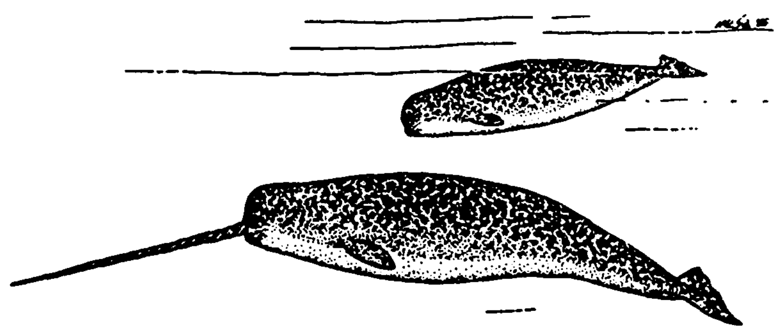


ICE STRESS CRACKS (AFB-37.5 Hz)



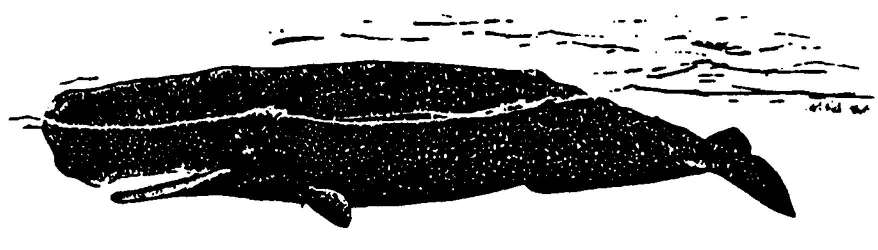


Beluga whale, spectrum of chirps and whistle chorus (1.6 sec. average, above), whistle waveform (below). AFB-37.5 Hz

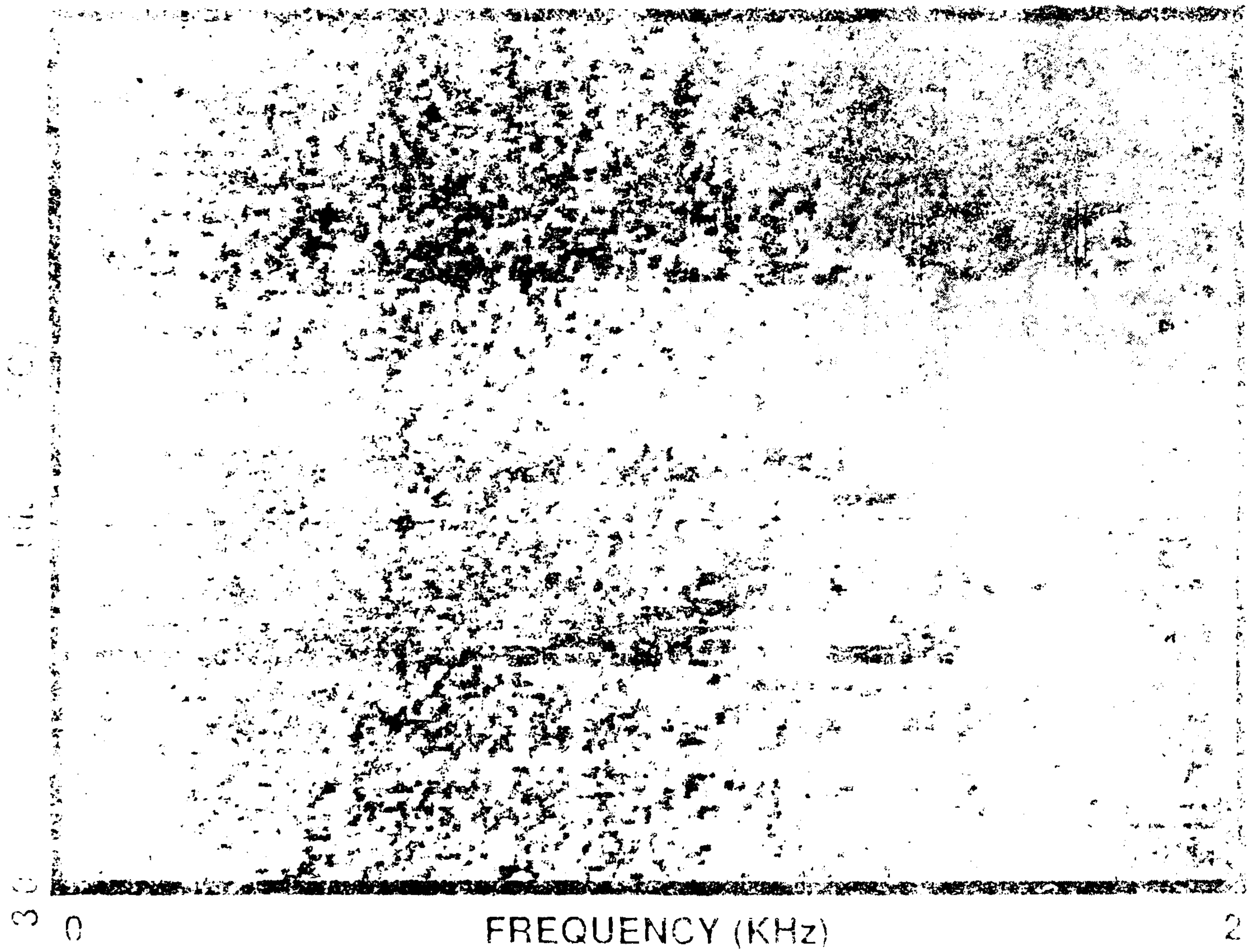
SOURCE	***NAW Narwhal, Monodon monoceros***
DISTRIBUTION	Circumpolar, all of Arctic Ocean and bordering seas. More common off Soviet Union. Deep water species. Along with Beluga and Bowhead whale, most Arctic of all cetaceans. Found on the very edge of pack ice, in heavy ice floes.
NUMBERS	Conservative 10 thousand off Canada, NW Greenland. Total population unknown, perhaps to 50 thousand. May be in pods of 150 animals.
LIFE HISTORY	Narwhal means "corpse whale" in Norwegian, for its appearance in the water. Size: to 4.7 m. Color: slate gray at birth, increasing to white mottling; adults are white on undersides and black dorsally with some mottling remaining on sides. Left front tooth develops into long tusk on males (the most distinguishing feature), sometimes on females, used for aggressive behavior. Food: Arctic cod, halibut, squid, crustacea. Calving: about mid-July, 15 mo after conception in mid-April; probably one calf every 3 yrs. Summers in deep bays and fjords. Can be greatly sensitive to man-made noise. 
TRANSIENT OCCURRENCE	Noisy. High frequency clicks at 4-370/sec with a fairly constant repetition rate. Pulsed tones. Narrrowband clicks.

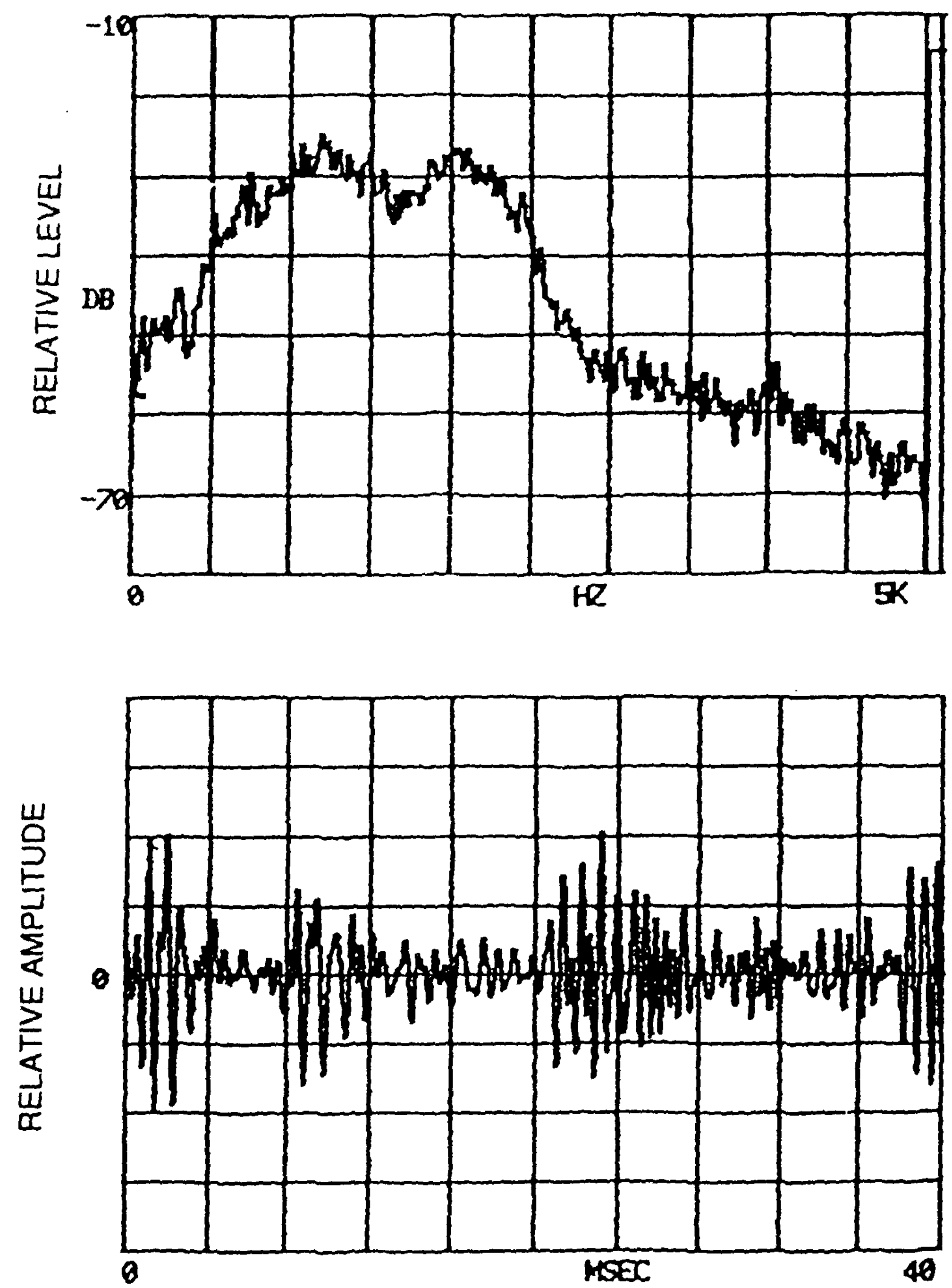
TRANSIENT DATA

SUBJECT	**Narwhal: clicks, whistles, pulsed tones**
DATE	August 1965, 1968, 1975
LOCATION	Off Baffin and Ellesmere Islands, Canada
CONDITIONS	Recorded from a boat, 10-12 animals slowly moving past (1965), 50 milling about at a distance of around 100 m (1968). Calm sea, surface temperature of 3 deg. C, partly overcast, subgroups of a total of 150 animals coming within 20 min of hydrophone (1975).
TRANSIENT DESCRIPTION	Clicks, unlike those recorded from other odontocetes, are very narrowband, evenly spaced impulses that occur between 1.5 and 24 kHz. Each click is composed of 7-10 cycles of the fundamental. Clicks in long series are 19-24 cycles. Repetition rates vary to 500/sec. Tonal sounds (short squeals) last a maximum of 6 sec in the frequency band of 0.3-18 kHz. Tones are generally of constant frequency (Hz), although some sweep up or downwards. Pulsed tones are variable in terms of duration and frequency, such that some appear as screams and others as growls. It is questionable whether click series are used for echolocation, communication, or both.
DATA SOURCE	Hubbs-Sea World, C. Ray, J. Ford, H. Dean Fisher, W. Watkins (suitable tape recordings unavailable for analysis)
SERIAL	**NAW**

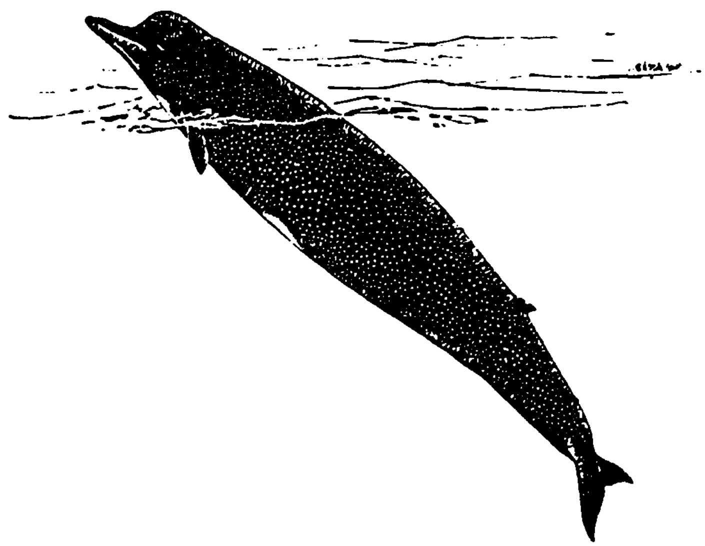
SOURCE	***SPW Sperm Whale, Physeter catodon***
DISTRIBUTION	N Atlantic: to 65-70 deg, Norwegian coast, Denmark and Davis straits, off Newfoundland, Nova Scotia. N Pacific: Bering Sea, S of Bering Strait, near Aleutians, 2-3 stocks. Males venture further N than females.
NUMBERS	For all Arctic, sub-Arctic waters, population size largely unknown. Atlantic: 20-80 W, 10-70 N, perhaps 20 thousand. NW Pacific: about 200 thousand.
LIFE HISTORY	Size: to 15 m, largest toothed whale. Appearance: all teeth in lower jaw, famous as objects of scrimshaw, single blowhole to left of body midline (blow shoots forward); no dorsal fin as such, but knuckles present, as on gray whale; head, 1/3 body length. Color: dark gray with pale belly region. Calving: each 3.5-4 yrs. Dive: to 2500 m, to 90 min, followed by up to 80 blows. Swims to km/hr for short distances. Large pods may number in the 100s. Much surface activity, e.g., breaching, lobtailing, thrusts. Occurs in open, midoceanic regions. Supposedly, an albino of this species was the origin of Moby Dick. 
TRANSIENT OCCURRENCE	"Carpenter fish" by virtue of trains of clicks, 1-100s/sec. Loud click choruses.

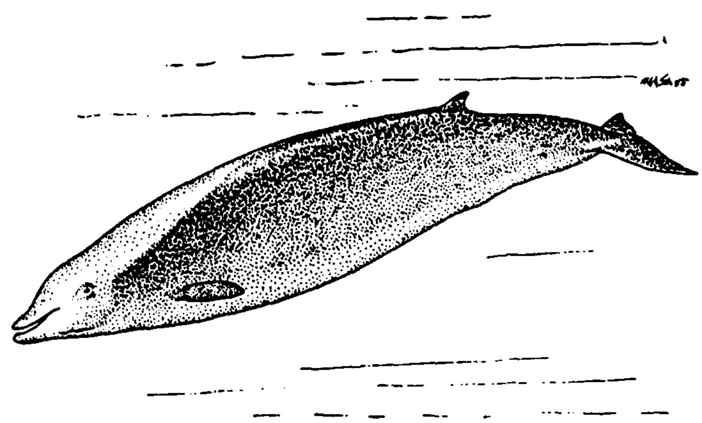
SUBJECT	**Sperm Whale: clicks, knocks**
DATE	First recorded 1952-1954
LOCATION	NW Atlantic, Caribbean
CONDITIONS	Open water, far to sea, calm to sea state 7
TRANSIENT DESCRIPTION	Virtually the entire repertoire of sounds from this species consists of clicks and knocks. Rarely has anything else been recorded. Monitored tapes revealed a 5-7 kHz squeal. Squawks, yelps and rasps have been recorded, but identity of these other sounds is questionable. The pulsive sounds vary in repetition rate from several in 0.1 sec to > 1/sec. Pulse length is up to about 1 sec in duration, but reverberation will extend the apparent duration to several seconds. The bandwidth of each pulsive sound varies from as low as 0.2 to > 30 kHz. Although pulses could be used by sperm whales for active sonar, some authors also think that information may be conveyed between animals, based primarily on time coding, hence the term "coda" as presented by Watkins. In the military sonar community, these sounds used to be called "carpenter fish" before being identified as sperm whale sounds. Navy sonar during the Grenada intervention was believed to quiet sperm whales and cause them to disperse. Source level is up to 180 dB, and target strength at 1 kHz is 106-107 dB, bow aspect, and 100-110 dB on the beam. Sounds are rarely encountered near the coast, because the species occurs far at sea. Sounds can be expected to originate at depths of > 2000m.
DATA SOURCE	H.E. Winn, W.A. Watkins, W.E. Schevill, W. Whitney, W.C. Cummings
SERIAL	SPW

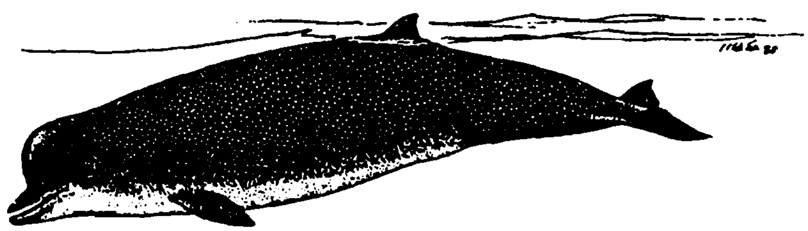




Sperm whale, peak hold spectrum of click train (5 sec., above), waveform of 3.5 clicks (below). AFB 18.75 Hz

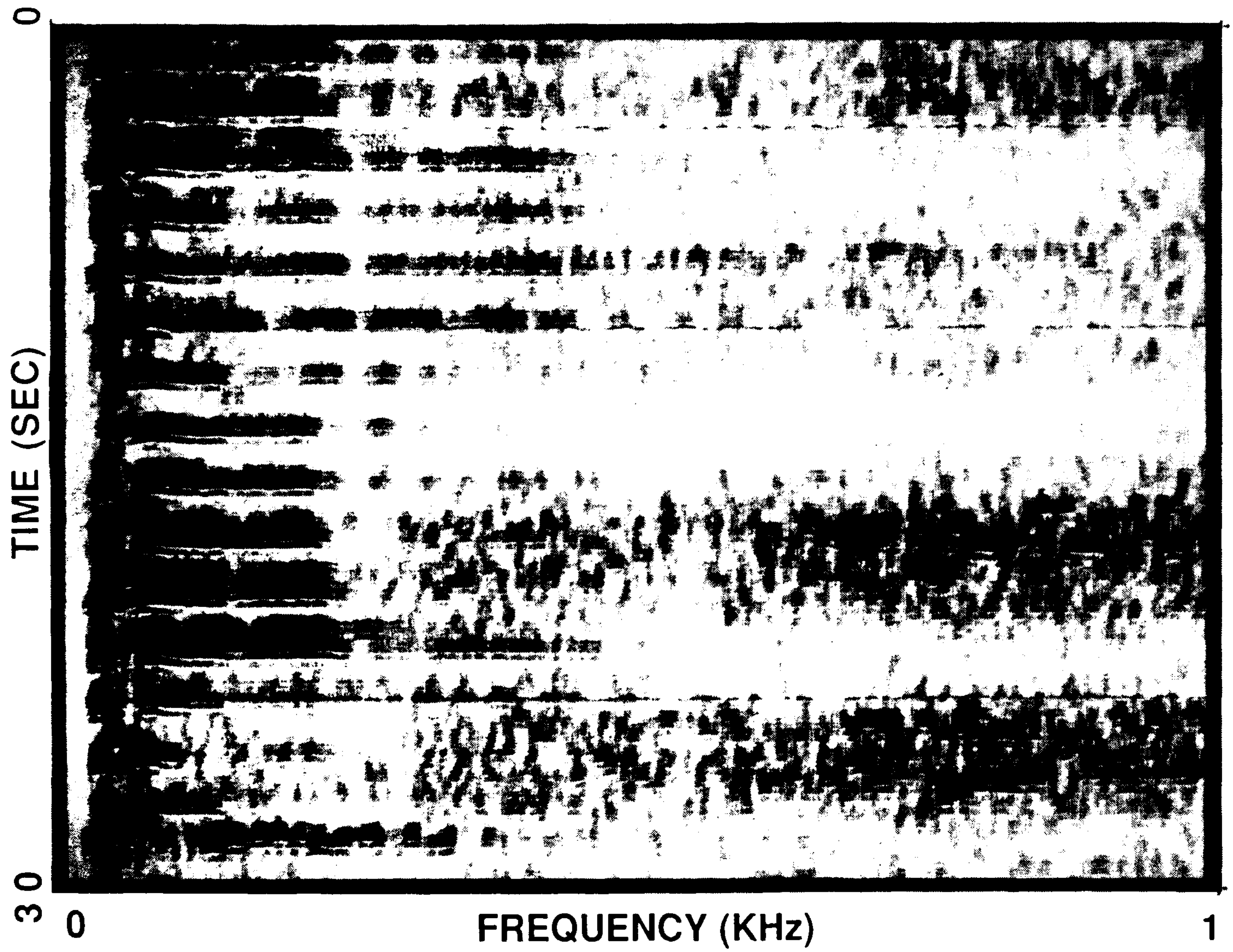
SOURCE	***PBW N Pacif.Giant Bottlenose Whale, Berardius bairdii***
DISTRIBUTION	Found only in the N Pacific. Okhotsk and Kamchatka regions, S to Alaska and Pribilof Islands, Bering Islands and Sea. Usually in waters deeper than 1000 m.
NUMBERS	Unknown, but hundreds/yr were taken in Japan's fishery.
LIFE HISTORY	Size: males to 12 m, females, 13 m. Breeding: late November-early May. Calving: November-May, peak in February. Appearance: slate gray, lighter on undersides, some white spots. Food: mainly deep sea fishes and squids. May occur singly, but usually in tight schools of 10-30. Dive: stays on surface 3-7 min, may spout 10-20 times and usually submerges 10-20 min; when harassed, as during hunting. May stay submerged to 1 hr. Visible blow is widespread and low to the water. 
TRANSIENT OCCURRENCE	Sounds unknown, but they doubtlesss produce sound and use active sonar.

SOURCE	***GBW Goose Beaked Whale, Ziphius cavirostris***
DISTRIBUTION	In all oceans except for the highest latitudes. Bering Sea, Alaskan waters in N Pacific; in Atlantic, as far north as N Sea. Also called Cuvier's whale.
NUMBERS	Unknown, but taken in small numbers in the small whale fishery of Japan.
LIFE HISTORY	Size: males to 6.7 m, females, 7 m. Found well out to sea in small groups. Dive: remain on surface for about 10 min, may stay submerged for 1/2 hr or longer, believed to be deep divers. Food: deep-sea fishes and squids. 
TRANSIENT OCCURRENCE	Sounds unknown

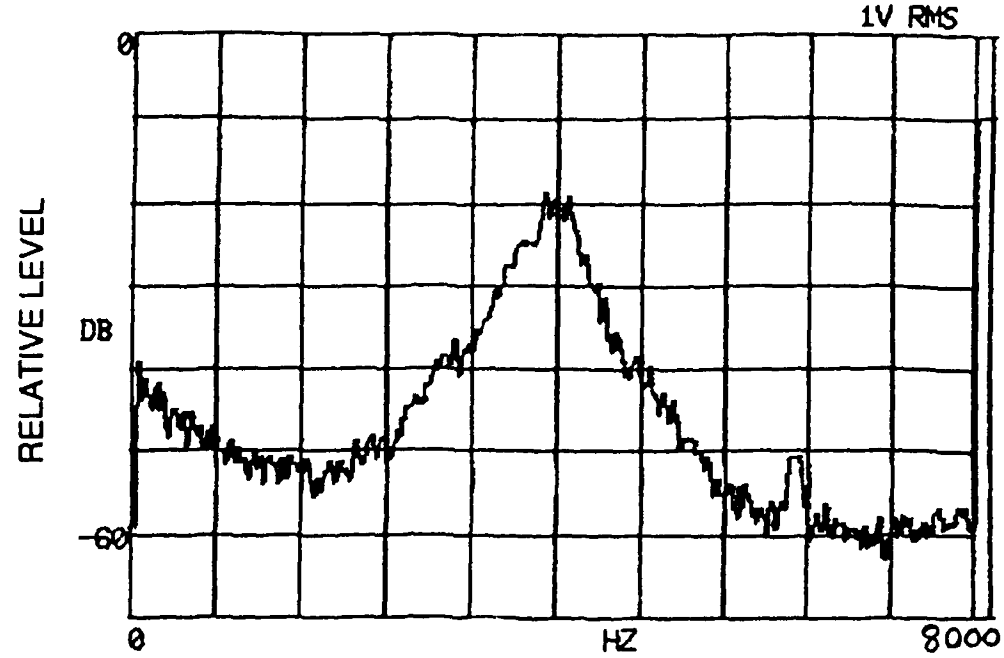
SOURCE	***ABW Atlant. Bottlenose Whale, Hyperoodon ampullatus***
DISTRIBUTION	N Atlantic: Newfoundland N to Labrador Sea, Davis Strait and Iceland; Greenland, Norwegian, and deep Barents seas, Novaya Zemlya, Svalbard (Spitsbergen). N Pacific: some records referable to this species in Bering and Okhotsk seas.
NUMBERS	Unknown, probably 300 thousand.
LIFE HISTORY	Attains length of 9 m. Appearance: very prominent forehead which, together with rostrum, looks like a bottle; small eyes and sickle shaped dorsal fin. Color: charcoal colored on dorsal with light gray undersides. Food: fish and squid. Found in small schools, usually over deep water (800 Fa). Frequently breaches, erratic swimming behavior. 
TRANSIENT OCCURRENCE	Click trains of 3-50 clicks/82 s. Variable whistles and chirps.

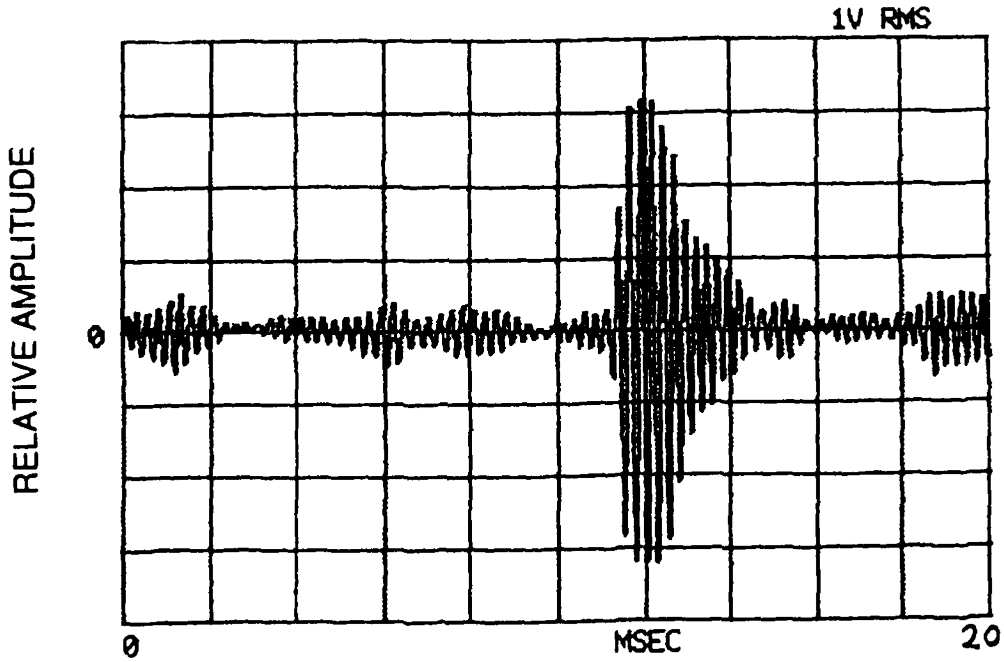
TRANSIENT DATA

SUBJECT	**Atlantic Bottlenose Whale: whistles, chirps, tones**
DATE	24-25 August 1969
LOCATION	100-800 Fa line, off Nova Scotia, 43 deg, 50' N; 58 deg, 56' W
CONDITIONS	Light winds, no white caps, excellent visibility. Encountered after playing back sperm whale sounds to pilot whales.
TRANSIENT DESCRIPTION	Whistles were 115-850 ms duration at frequencies between 3-16 kHz. Some were modulated, others were continuous wave, in the regions from 3-5, 7-9, and 12-14 kHz. One series of apparent tones was actually tone bursts of AM that displayed harmonics. The chirps start at about 4 kHz, and in 70-90 msec sweeps upwards to 13 kHz. Click trains were of 3-50 clicks, with repetition rates to 82/sec. The maximum frequency range of clicks was 0.5-26 kHz, all were single pulse. All sounds were of low amplitude, but levels are unavailable. Pulsed sounds were inaudible when the animals were > 30m from the ship. Broadband (almost white noise) blasts of 80-150 msec are also produced. Since this animal may dive to several hundred meters for as long as an hour (perhaps to 2 hrs), its sounds may occur near military receivers.
DATA SOURCE	H.E. Winn, P.J. Perkins, E. Mitchell, P. Beamish
SERIAL	**ABW**



ICE, SLUSH AND BUMP (AFB-3.75 Hz)





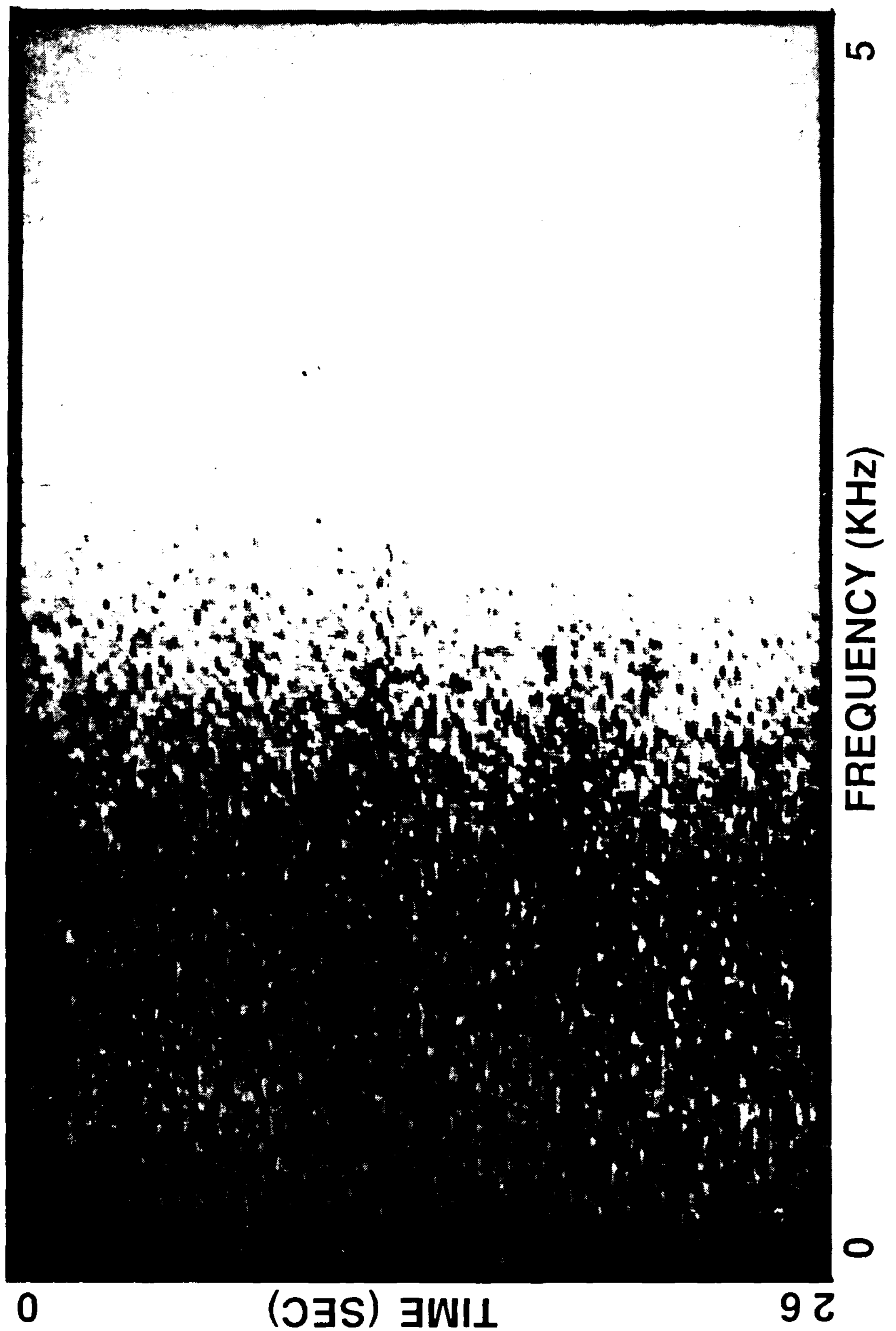
North Atlantic bottlenose whale, peak hold spectrum of click train (3 sec., above), waveform showing a single click (below). AFB 30 Hz

III. CATALOG

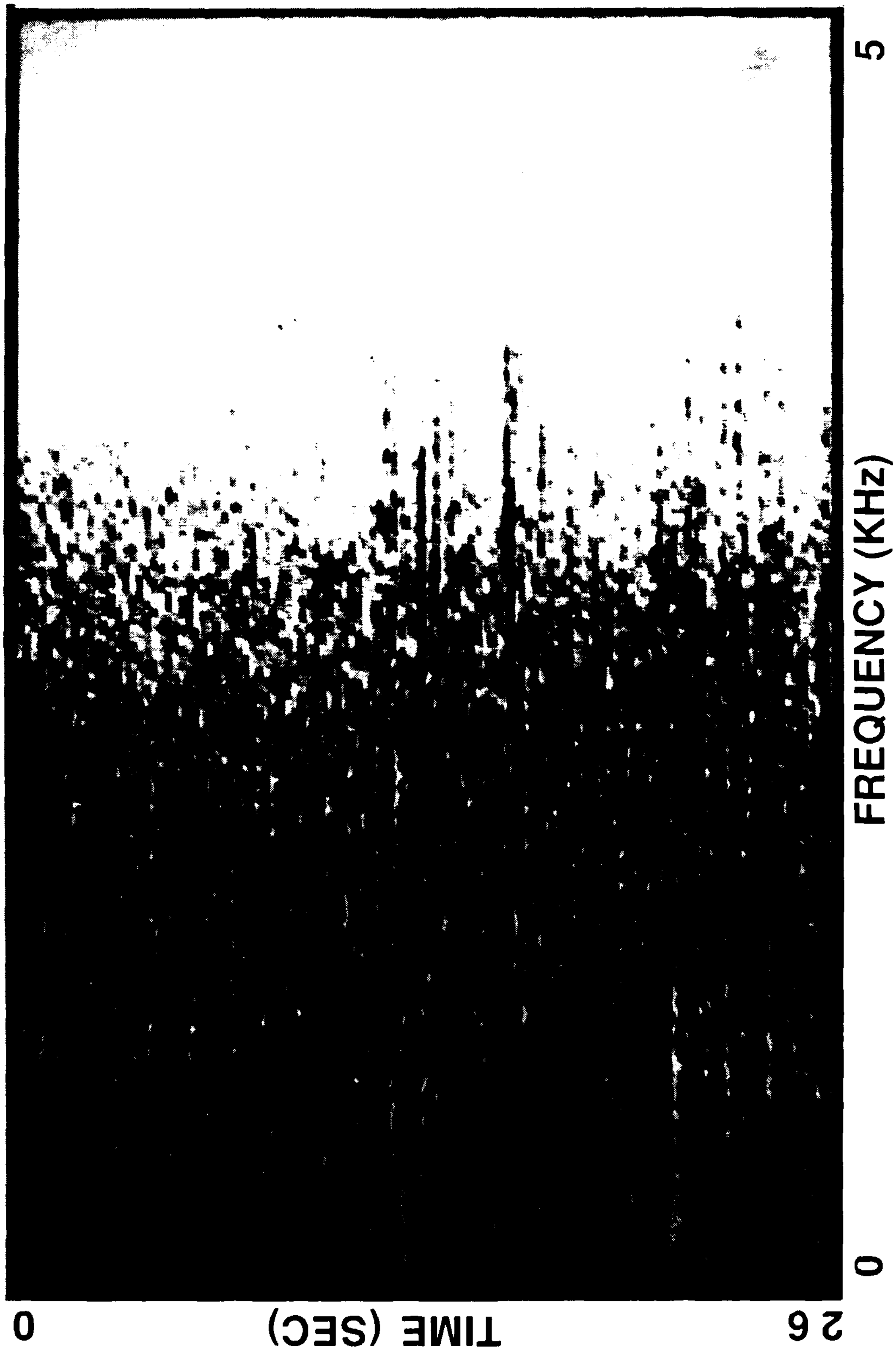
B. NATURAL PHYSICAL TRANSIENTS

TRANSIENT DATA

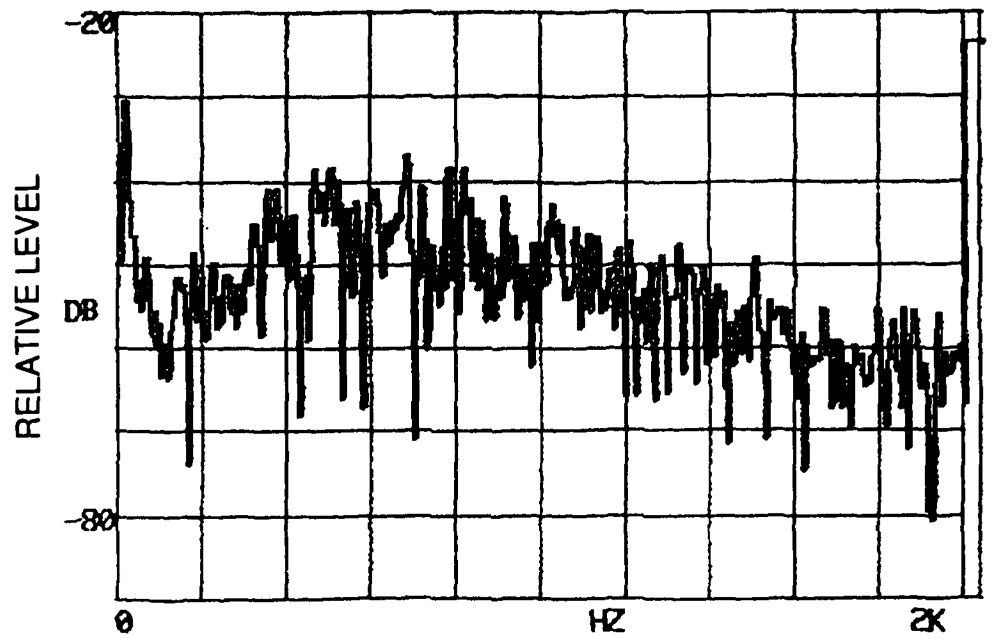
SUBJECT	**Ice Stress Cracks**
DATE	March 1984
LOCATION	Kotzebue Sound, Alaska
CONDITIONS	Solid winter ice. Wind, 2 mph. Air temperature, falling, -31 deg C. Water depth, 8 m. Hydrophone at mid depth, remotely sensed.
TRANSIENT DESCRIPTION	After continuously falling temperature and rapidly ceasing wind speed, ice cracking sounds appeared on all hydrophones of the array used for sound localization. Cracking sounds were associated with regions of high ice activity, i.e., refrozen cracks and small pressure ridges. Average source spectrum levels were 79 dB, in the water. Received energy extended to 10 kHz, with peaks in the region of 400-900 Hz. Impulses were in 1-4 parts. Duration, 0.1-0.3 sec, including reverberation.
DATA SOURCE	W.C. Cummings, D.V. Holliday, D. Bonnet
SERIAL	**ISC**

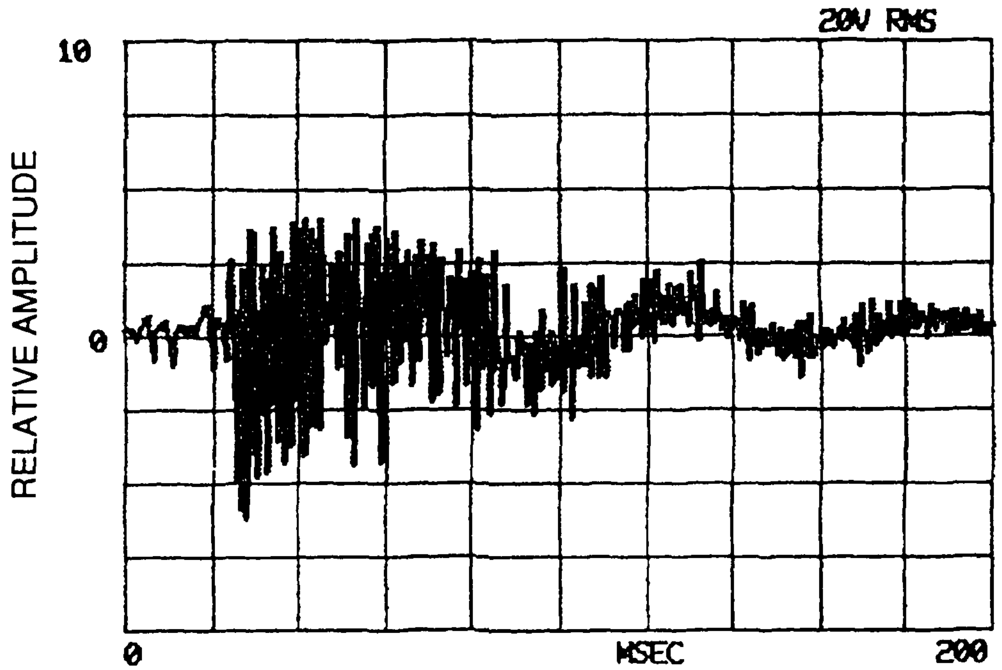


ICE SOLID BEFORE LEAD (AFB-18.75 Hz)

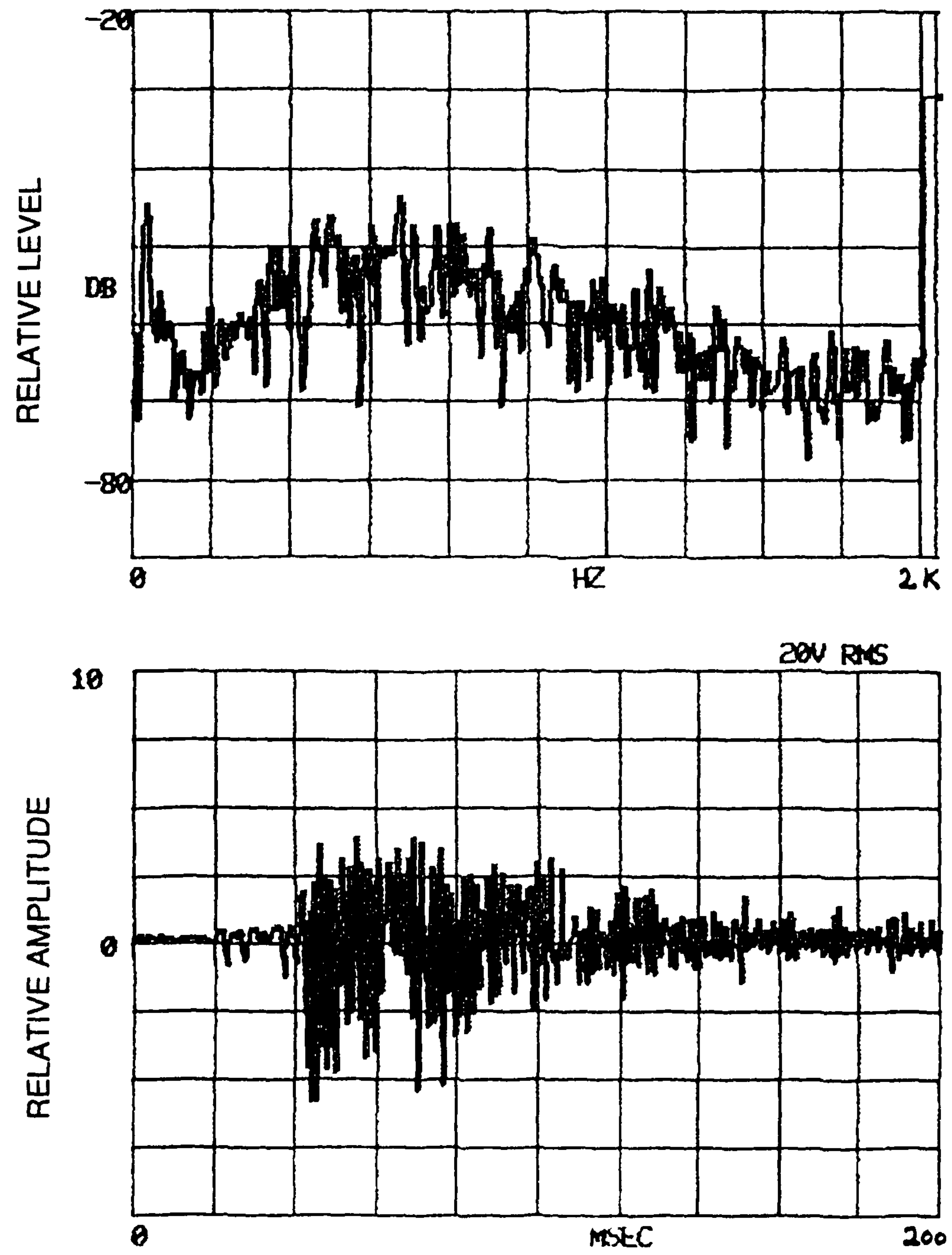


ICE LEAD OPENING (AFB-18.75 Hz)

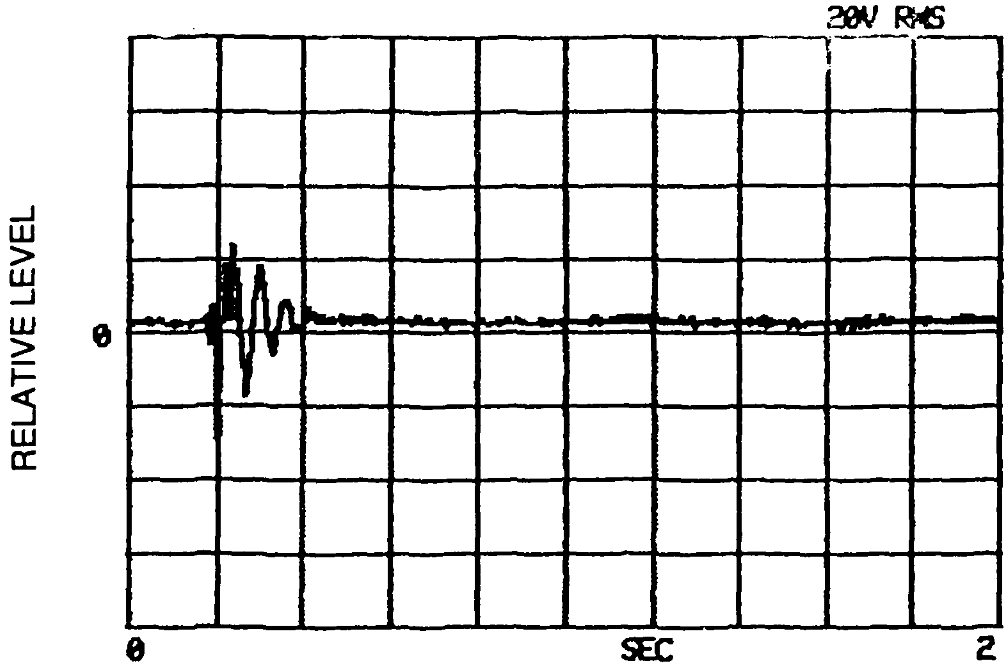


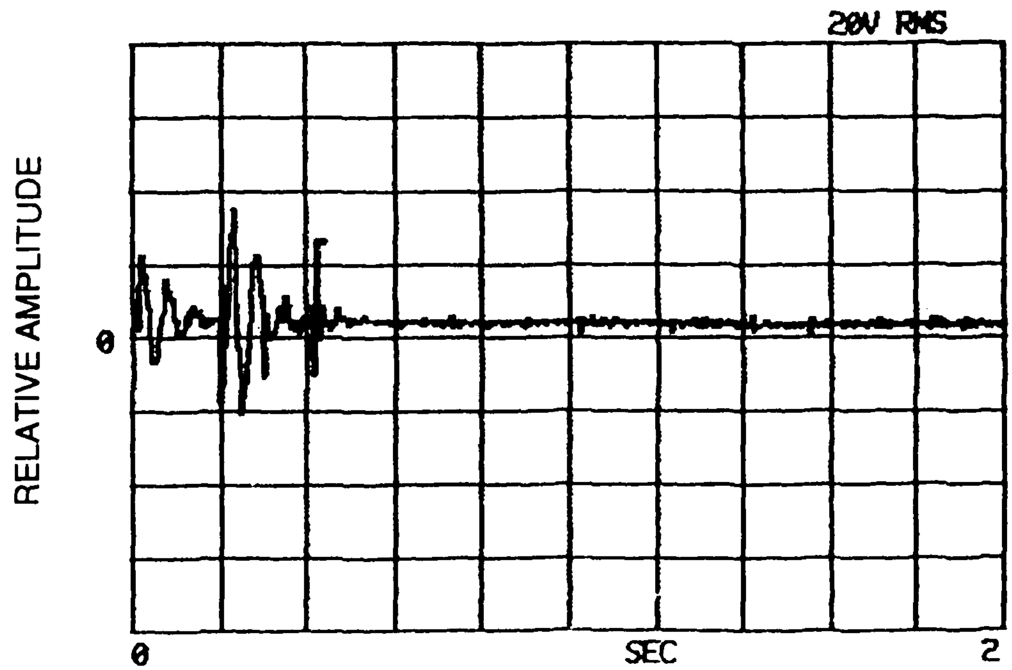


Ice, spectrum of single ice stress crack (above), waveform of single ice stress crack (below). AFB 7.5 Hz



Ice, spectrum of single ice stress crack (1.06 sec. average, above), waveform of same (below). AFB 7.5 Hz

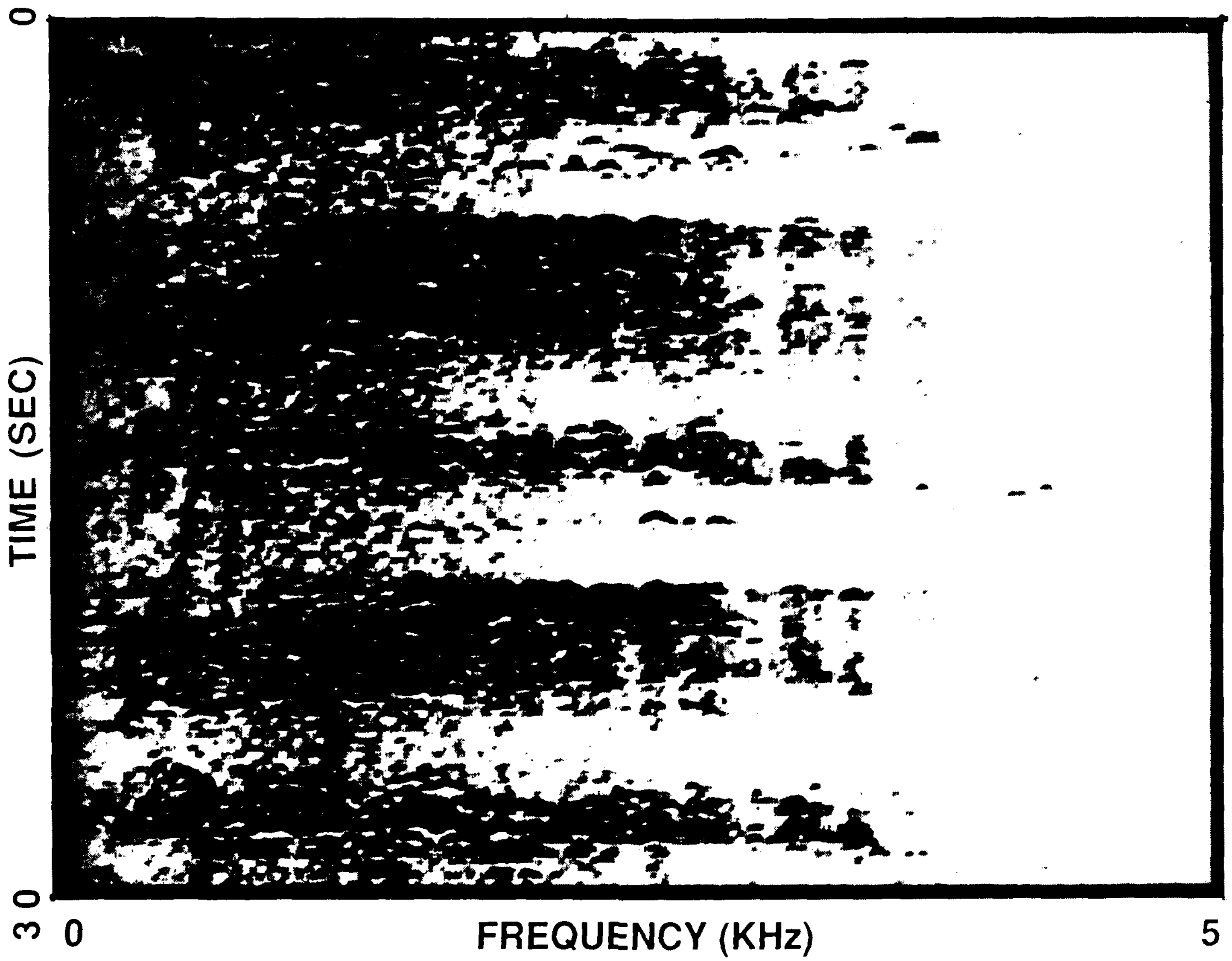




Ice, waveform of single ice stress crack (above), waveform of triplet ice stress crack (below).

TRANSIENT DATA

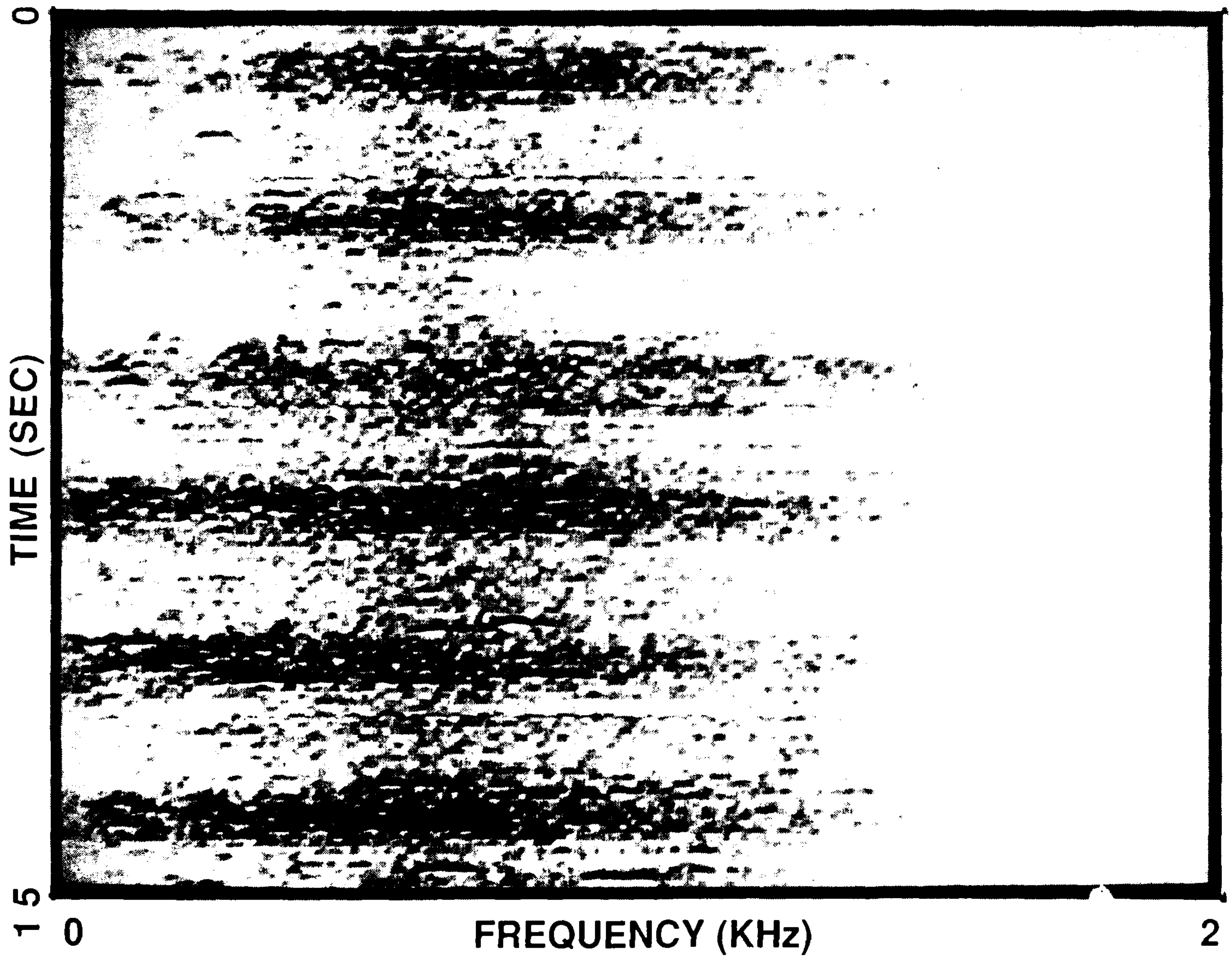
SUBJECT	**Ice Squeaks**
DATE	June 1980
LOCATION	Inshore edge of a 1.4-km lead, 5 km NW of Point Barrow, Alaska
CONDITIONS	Spring ice. Two large (about 1/4 acre) plates working against each other. Air temperature, 5 deg C. Water depth, 32 m. Wind, 6 mph.
TRANSIENT DESCRIPTION	Ice plate movement was caused by incoming swell from the lead. Squeak sounds were continuous over 4 days, until favorable winds pushed the offshore plate out into the lead. Peaks of energy appeared at 1-1.5 kHz, most sounds were < 2 kHz. Squeak durations were 0.5-3.2 sec.
DATA SOURCE	W.C. Cummings, W.T. Ellison
SERIAL	**ISQ**



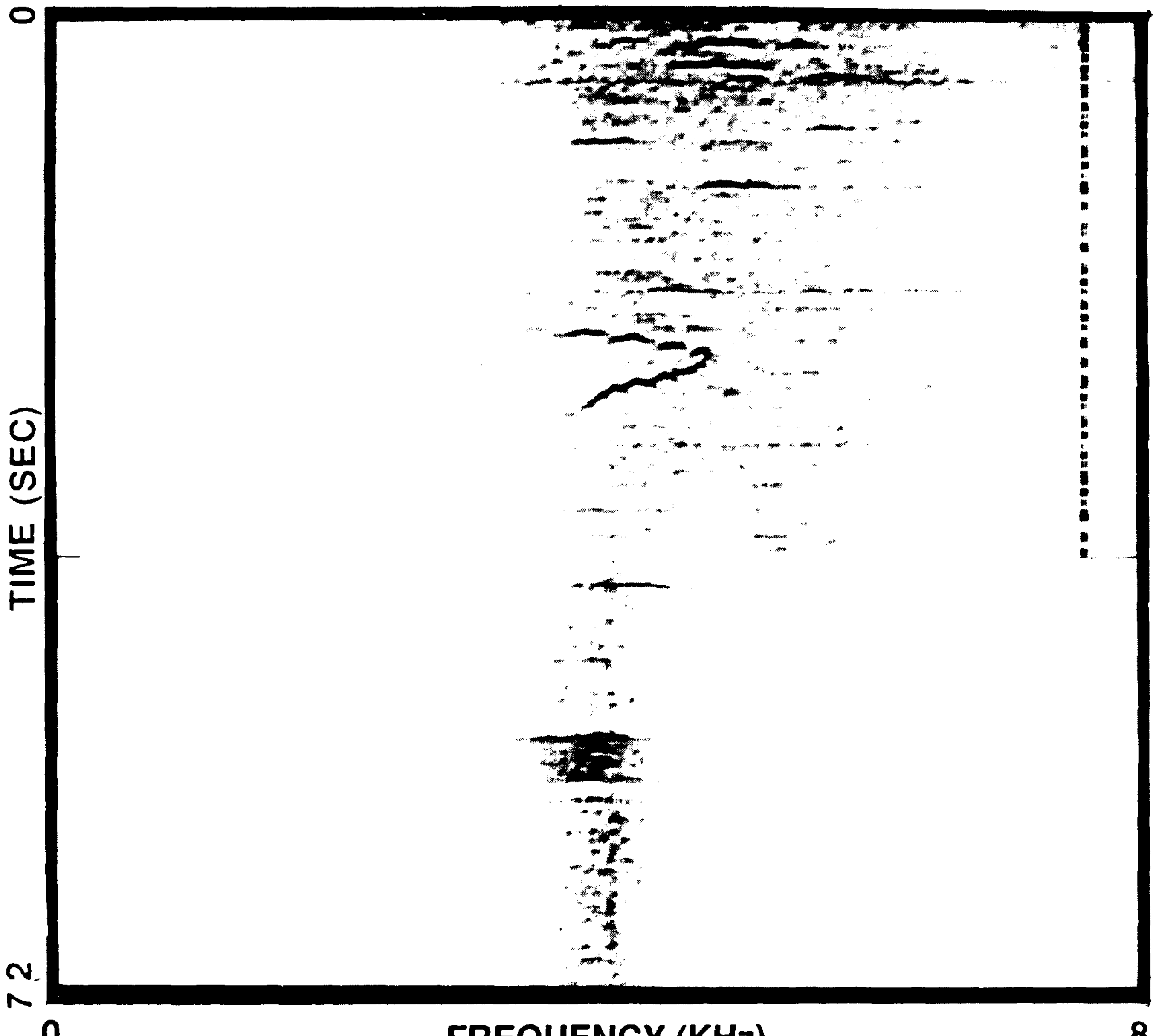
ICE. OPEN LEAD. BOWHEADS AND SEALS (AFB-18.75 Hz)

TRANSIENT DATA

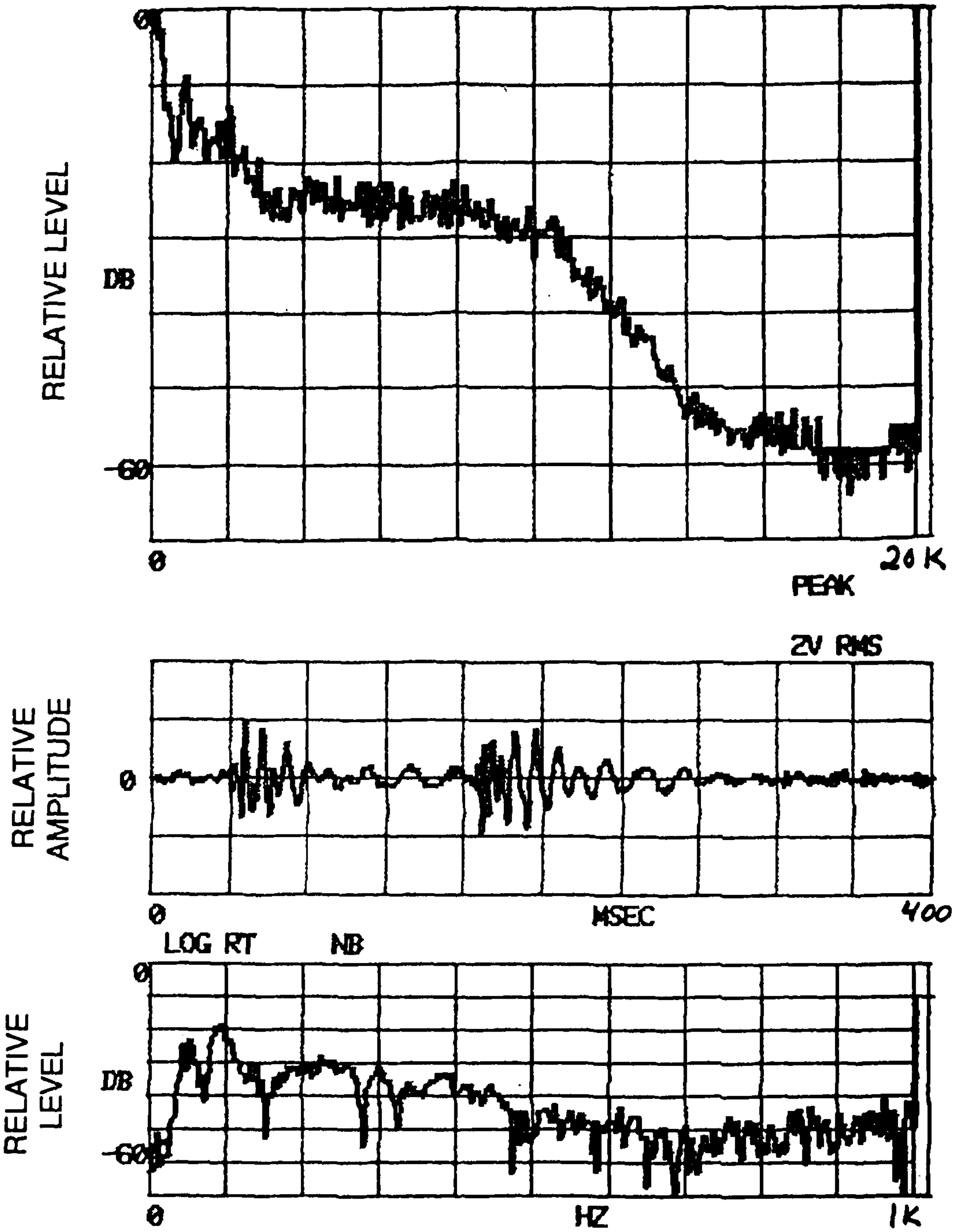
SUBJECT	**Ice Slush and Bump**
DATE	June 1980
LOCATION	1 km offshore, 3.3 km E of Point Barrow, Alaska
CONDITIONS	A 2-3 m lead opened in otherwise landfast ice. Water surface contained golf to basketball sized floating ice chunks.
TRANSIENT DESCRIPTION	Sounds were from impulsive collisions of ice chunks caused by swell movement of the water's surface. The background to these impulses was a constant swoosh from moving and colliding slush crystals. Energy extended to 14 kHz, peaks were 0.01-0.5 kHz, highest around 50 Hz. Sounds were of varied repetition rate. Duration range of collision impulses was 0.04-1.4 sec. These conditions and sounds lasted nearly 6 days when the little lead became frozen from a sudden drop of temperature. Colliding resumed in 2 days when the lead opened up again.
DATA SOURCE	W.C. Cummings, W.T. Ellison
SERIAL	**ISB**



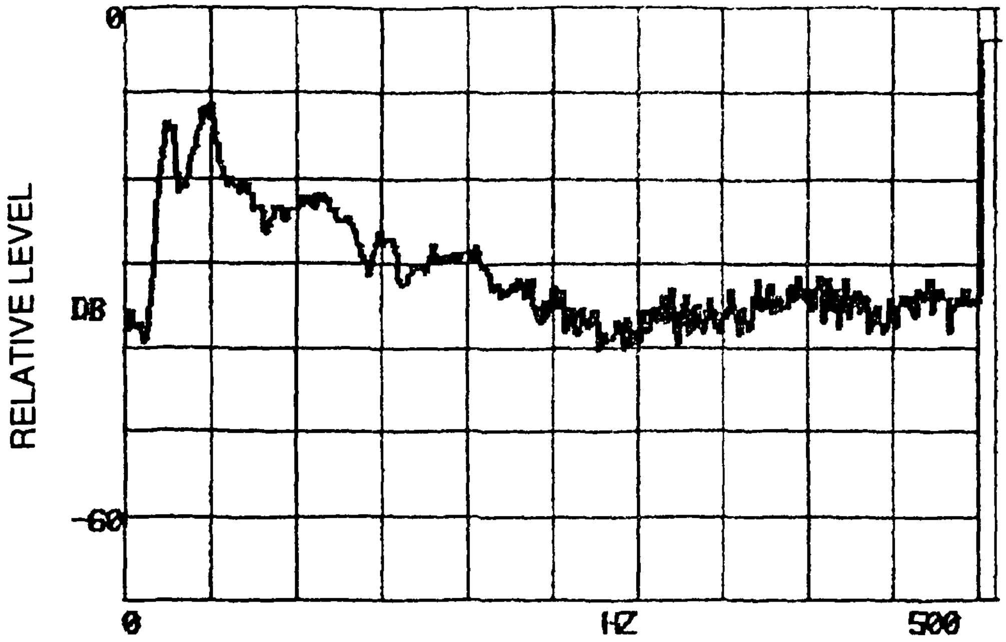
ICE, WAVE SLAPS (AFB-7.5 Hz)

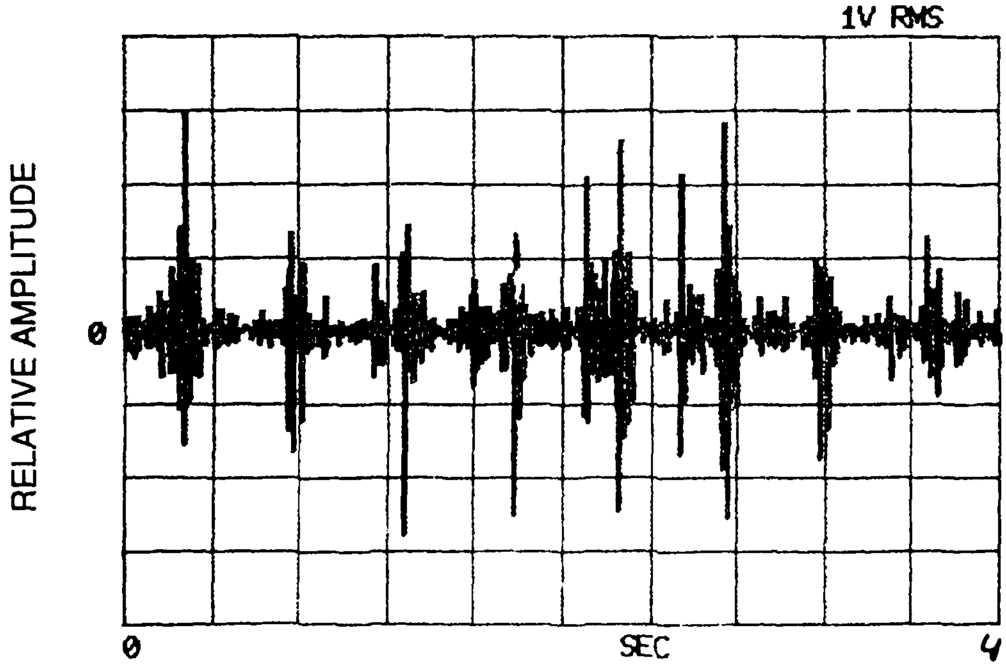


NO. ATLANTIC BOTTLENOSE WHALE WHISTLES, PULSE BURST, FILTERED (AFB-30 Hz)



Ice, peak hold spectrum of slush and bump sounds (7.5 sec., above), waveform of two bumps and their spectra (below).
AFB 75 Hz (above) 3.75 Hz (below)

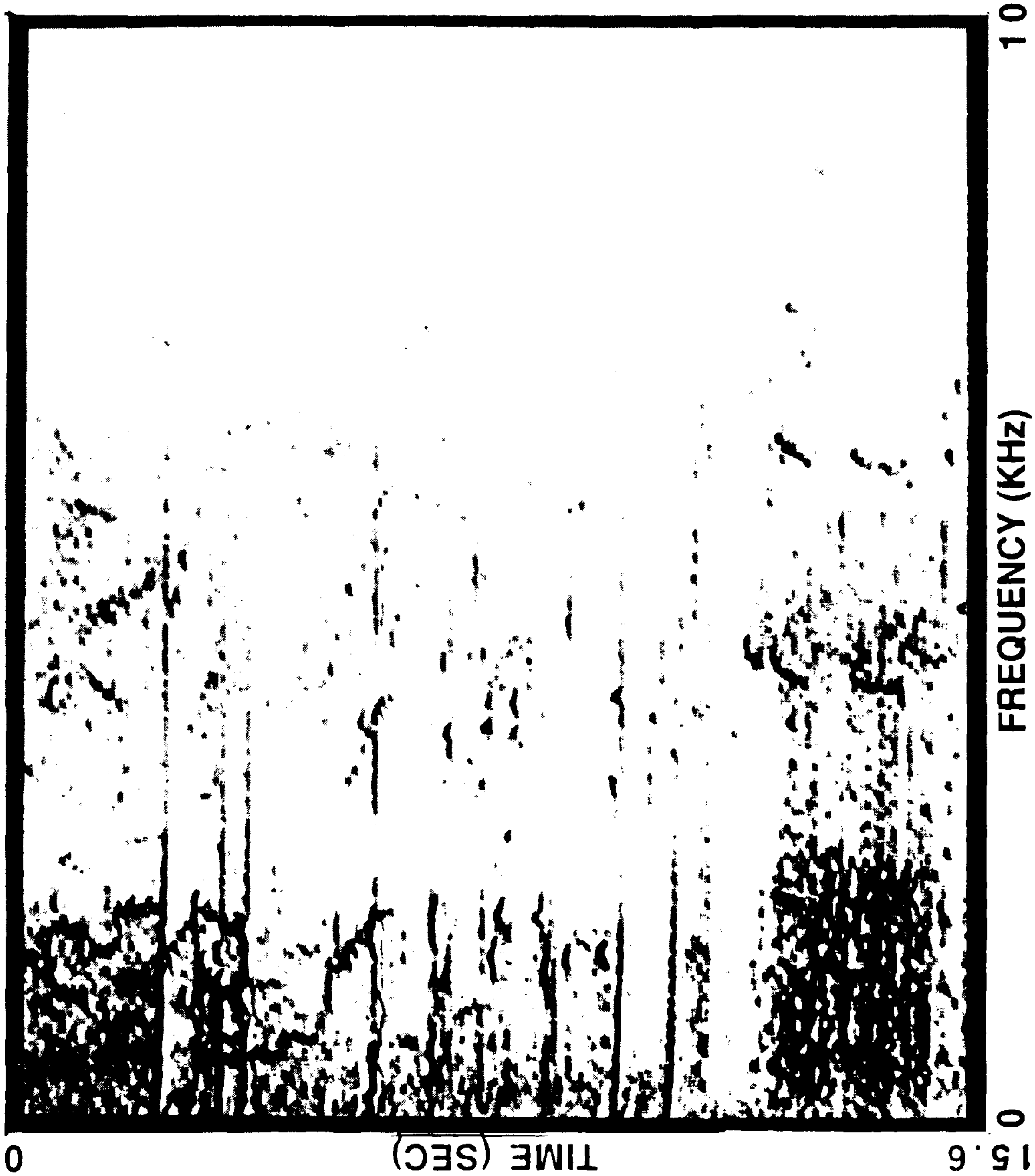




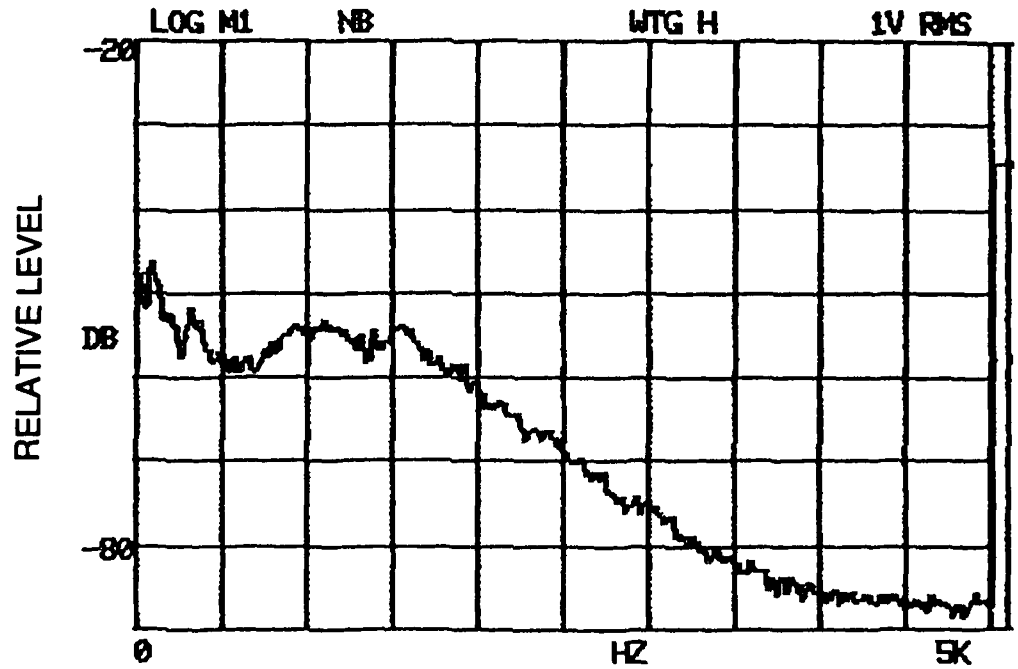
Ice, peak hold spectrum of slush and bump sounds (10 sec., above), waveform , 13 bumps (below). AFB 37.5 Hz

TRANSIENT DATA

SUBJECT	**Ice Solid, before lead opening**
DATE	May 1982
LOCATION	11 km E of Point Barrow, Alaska
CONDITIONS	Hydrophone on edge of closed lead, near grounded ice ridge, 19 m water depth. Southerly wind, 4 mph. Hydrophone at middepth, remotely sensed.
TRANSIENT DESCRIPTION	Quiet conditions. Only transients were occasional ice cracks or distant, very low level (S/N ratio of 2 dB) biologics consisting of bearded seal and beluga whale. Ambient noise peaked at 100 Hz region. Broad concentration of low-level noise at 700-1700 Hz.
DATA SOURCE	W.C. Cummings, D.V. Holliday
SERIAL	ISO



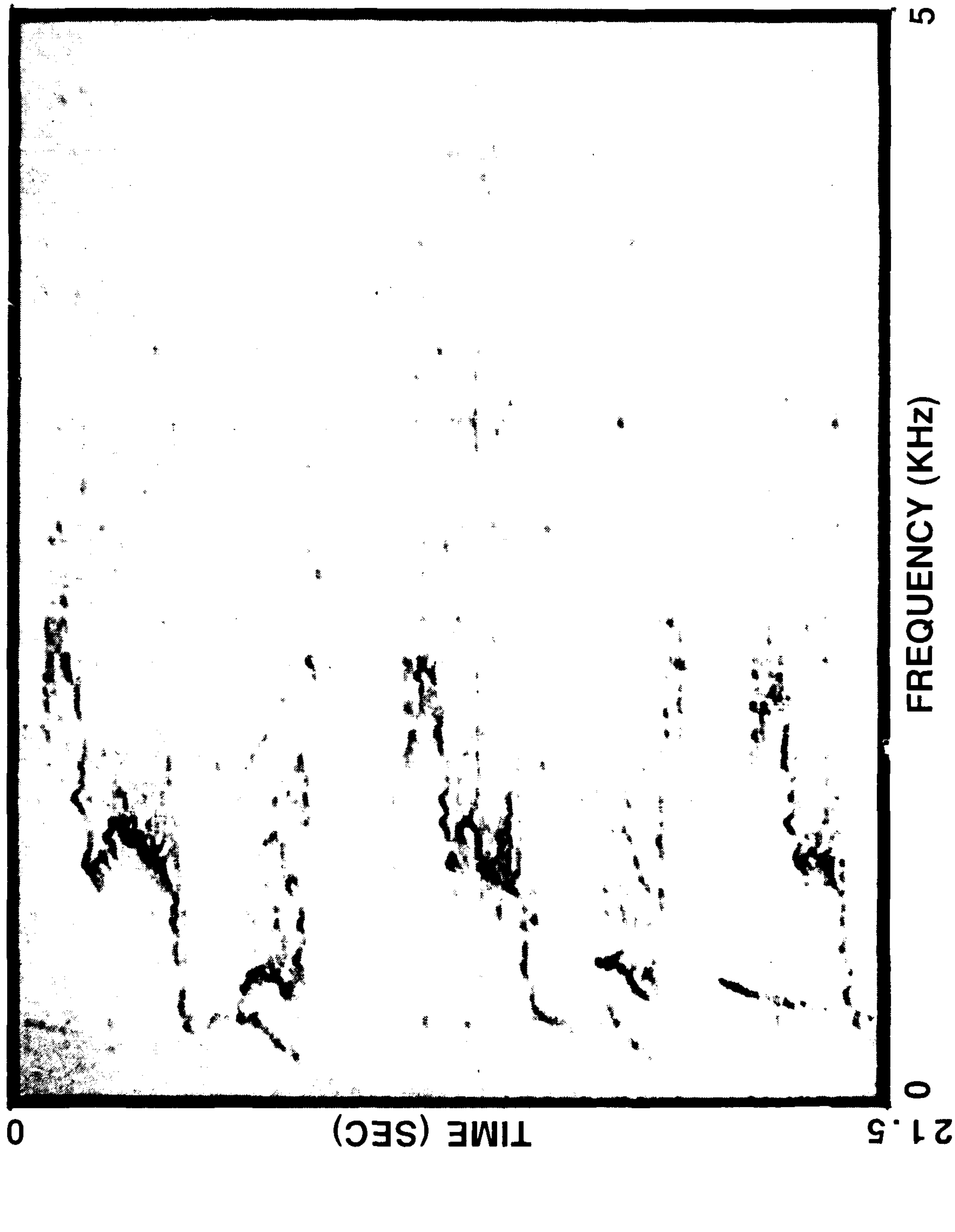
BELUGA CHIRPS, WHISTLES (AFB-37.5 Hz)



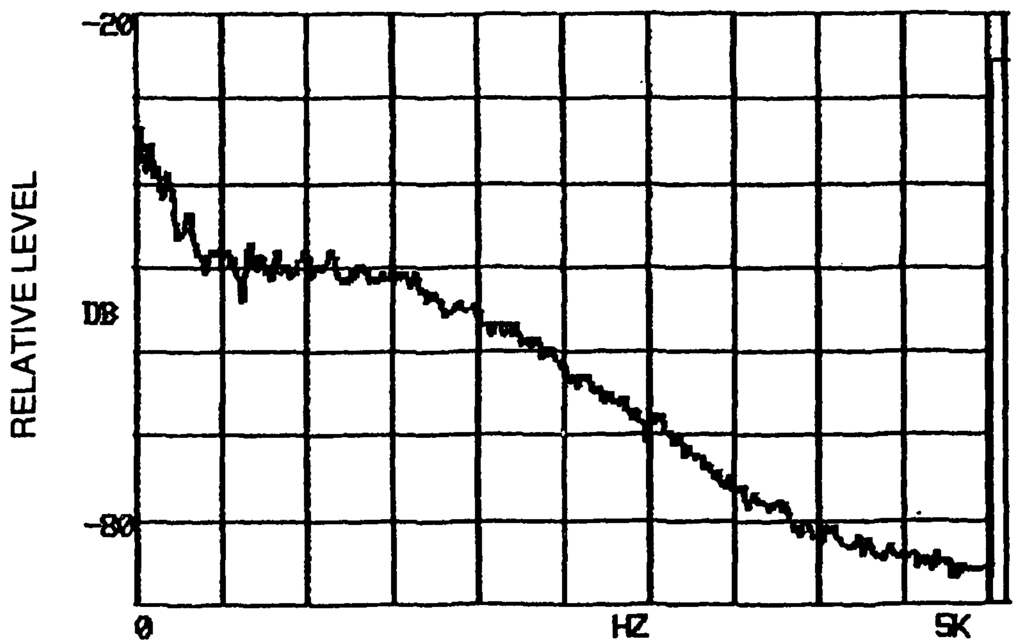
Ice, average spectrum of solid condition before lead opens (2.9 sec). AFB-18.75 HZ

TRANSIENT DATA

SUBJECT	**Ice Lead Opening, after closed condition**
DATE	May 1982
LOCATION	11 km E of Point Barrow, Alaska
CONDITIONS	Hydrophone on edge of closed lead, near grounded ice ridge, 19 m water depth. Southerly wind, 4 mph. Hydrophone at middepth, remotely sensed.
TRANSIENT DESCRIPTION	Numerous ice cracks, collisions, squeaks, and increased (over previous condition) numbers of beluga whale sounds. High-level transients noted to 4 kHz. Overall RMS level of the noise was 10 dB > previous levels from closed lead, a few hours earlier.
DATA SOURCE	W.C. Cummings, D.V. Holliday
SERIAL	ILO



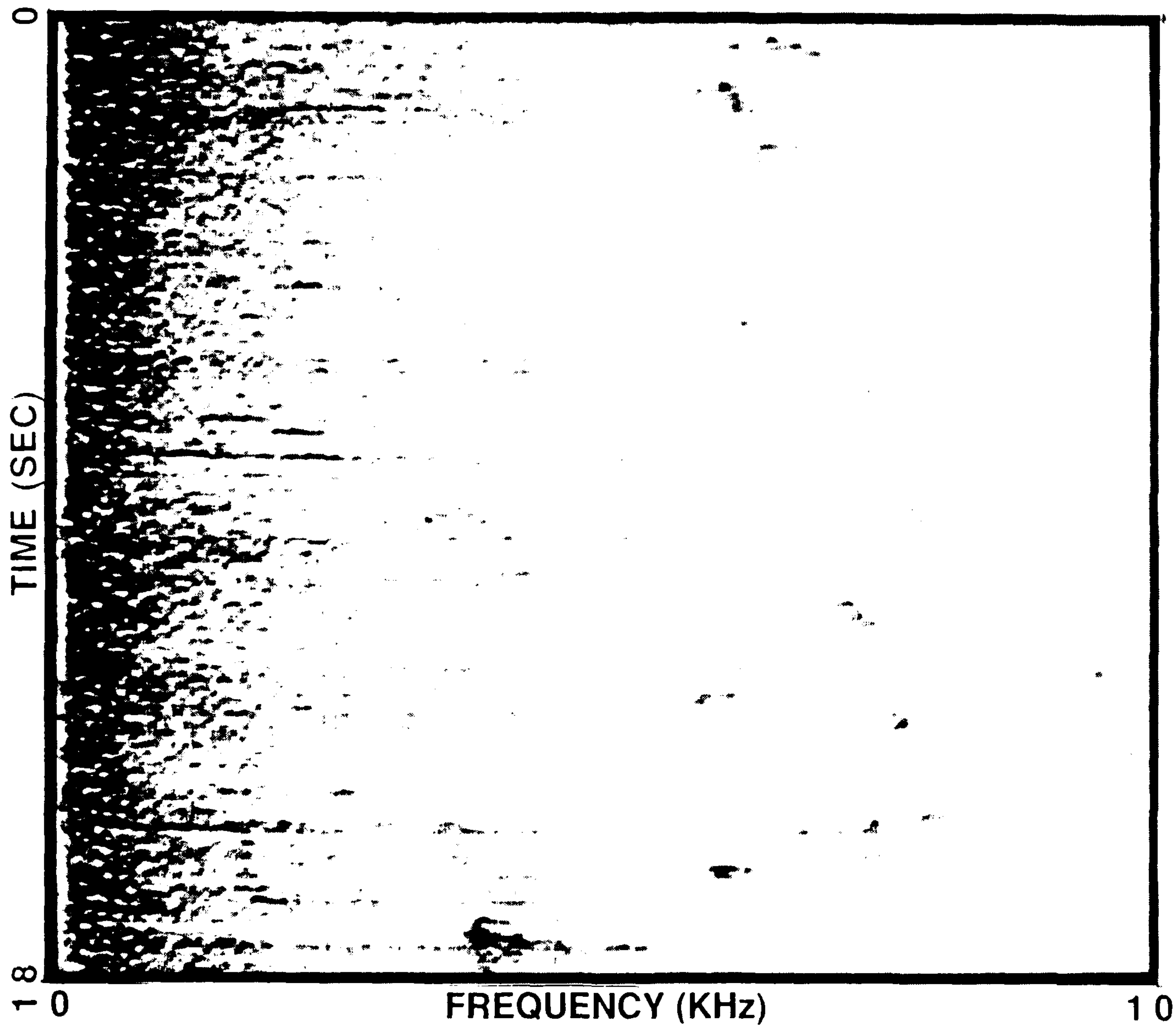
BOWHEAD WHALE SONG PHRASES (AFB-18.75 Hz)



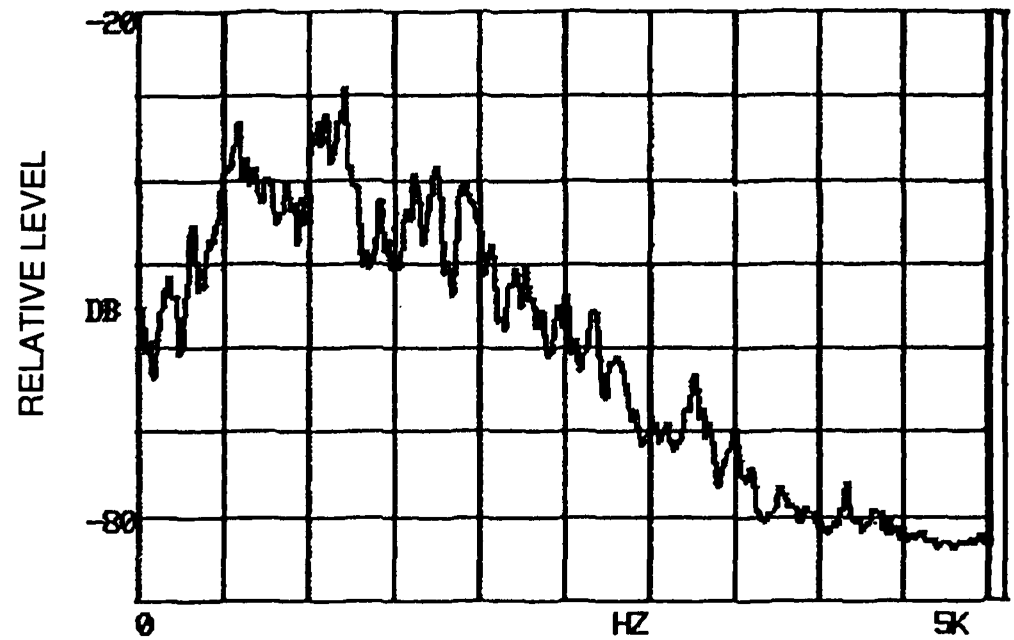
Ice, average spectrum of lead while opening (2.9 sec.)
AFB-18.75 HZ

TRANSIENT DATA

SUBJECT	**Ice Open Lead, after closed and then opening conditions**
DATE	May 1982
LOCATION	11 km E of Point Barrow, Alaska
CONDITIONS	Hydrophone on edge of closed lead, near grounded ice ridge, 19 m water depth. Southerly wind, 4 mph. Hydrophone at middepth, remotely sensed.
TRANSIENT DESCRIPTION	High-level transients consisting of wave slap, ice collision, bowhead whale song elements, beluga whale and bearded seal sounds (see those transient descriptions in this catalog). Transient levels highly peaked in the 0.4-2 kHz region of the noise spectrum. Overall noise levels (RMS) now 30 dB > that level when the lead was closed, 8 hrs earlier.
DATA SOURCE	W.C. Cummings, D.V. Holliday
SERIAL	IOL



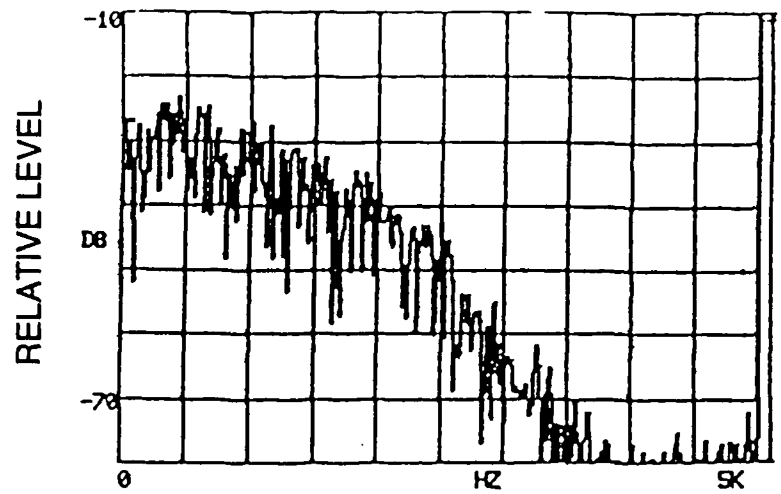
WHITE-BEAK PORPOISE CHIRPS (AFB-37.5 Hz)

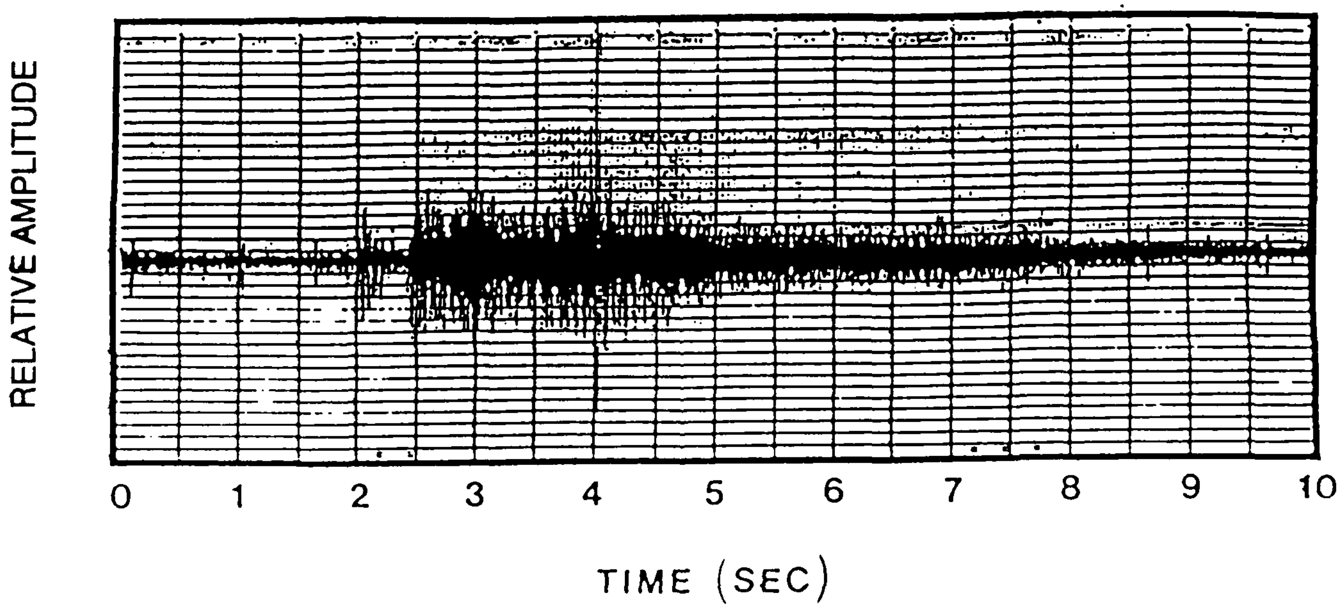


Ice, average spectrum of lead when opened (13.6 sec.).
AFB-18.75 Hz

TRANSIENT DATA

SUBJECT	**Ice Ridge Calving**
DATE	May 1982
LOCATION	11 km E of Point Barrow, Alaska
CONDITIONS	Hydrophone on edge of open, 2 km lead, near grounded ice ridge, 19 m water depth. Northerly wind, 8.2 mph. Hydrophone at middepth, remotely sensed. Temperature 10 deg C, ice thawing.
TRANSIENT DESCRIPTION	During spring warming, large pieces of ice break off from the edge of ridged ice and fall into the sea. The beginning of this calving sound consisted of several sharp impulses, followed by prolonged reverberation. It was a broadband, relatively powerful transient. Duration, 7.5 sec. Peak of energy, 350 Hz. Up to 3 calvings were heard in the area of the hydrophones during 3 days of thawing conditions. It became too dangerous to remain on the ice and camp was broken.
DATA SOURCE	W.C. Cummings
SERIAL	IRC

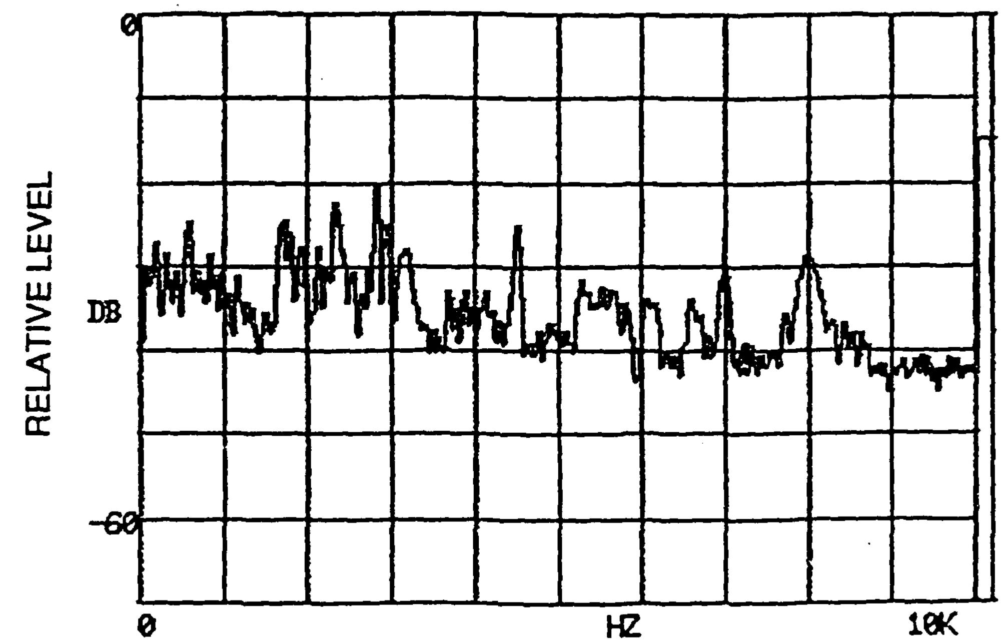




Ice, peak hold spectrum of ridge calving transient (8 sec., above), and time-compressed waveform of same (below). AFB 18.75 Hz

TRANSIENT DATA

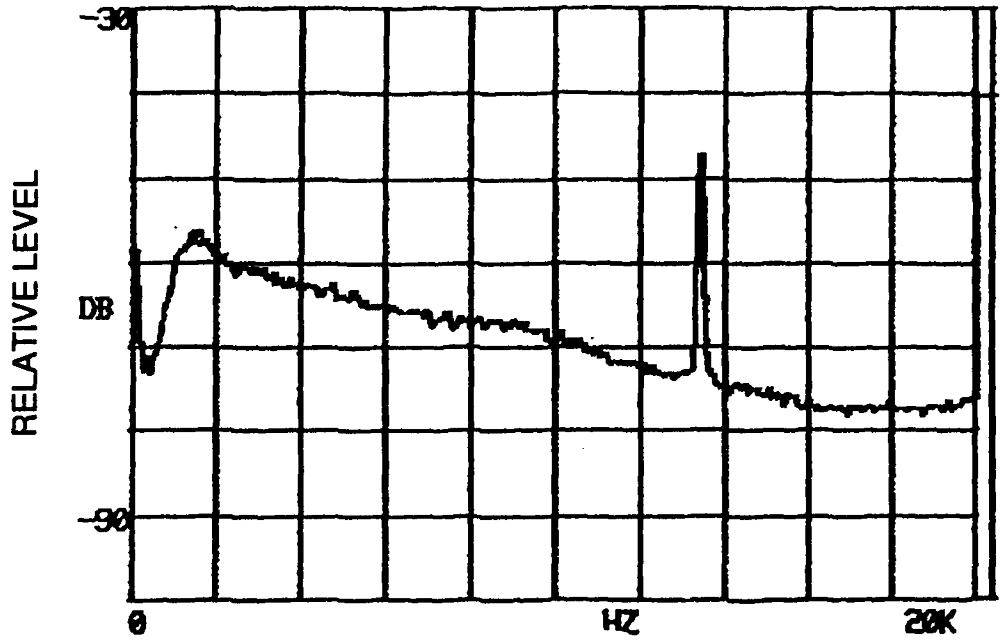
SUBJECT	**Ice Brine Trickle**
DATE	May 1982
LOCATION	11 km E of Point Barrow, Alaska
CONDITIONS	Hydrophone on edge of open, 2 km lead, near grounded ice ridge, 19 m water depth. Northerly wind, 5 mph. Hydrophone at middepth, remotely sensed. Temperature 11 deg C, ice thawing.
TRANSIENT DESCRIPTION	Aurally, this transient exactly duplicates that from pouring a trickle of fluid on the sea's surface. Although we have recorded this under winter ice conditions, in this instance the event occurred during thawing. The transient covered the spectrum to 18 kHz. In the first 10 kHz, there were noted peaks of 5-10 dB. We have never been able to isolate the specific location of brine trickle noises, in terms of seeing *it happen, and the* identification is based on sound characteristics alone. A total of 9 of these transients was noted in 8 days of the encampment on the ice.
DATA SOURCE	W.C. Cummings
SERIAL	IBR

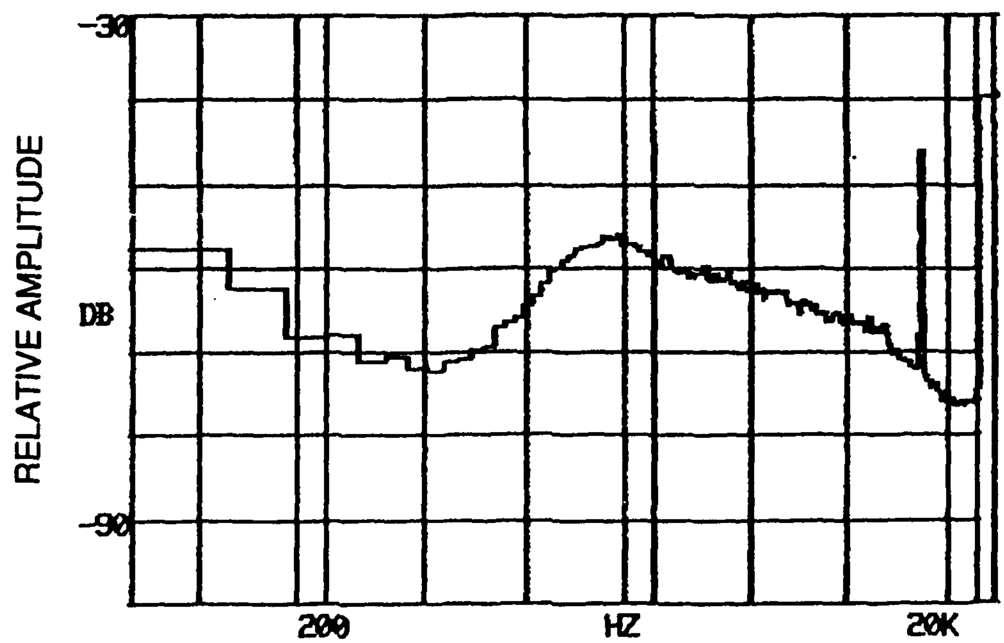


Ice and water, peak hold spectrum of brine trickle (6 sec.).
AFB-37.5 Hz

TRANSIENT DATA

SUBJECT	**Snow Pelting**
DATE	March 1983
LOCATION	Chukchi Sea, near International Date Line, W of Kotzebue Sound
CONDITIONS	Hydrophone suspended through a hole bored in ice where a polynya had been. Wind blowing at 8-10 mph caught snow and scattered it over the newly frozen ice.
TRANSIENT DESCRIPTION	Peak frequency was at 1500 Hz. The effect was broadband, i.e., > 20 kHz, with a slope of about 2.5 dB/octave. Aurally, the transient resembled a protracted swishing noise whose amplitude was positively correlated with wind gusts. The snow granules could be seen drifting across the new ice, which in some places had already accumulated a thin crust. Milne has described the actual cause of the noise to be impacts on the surface boundary that are then transmitted through compacted snow, the underlying ice, and then to the water below.
DATA SOURCE	W.C. Cummings, C. Lee, A. Milne
SERIAL	TSP

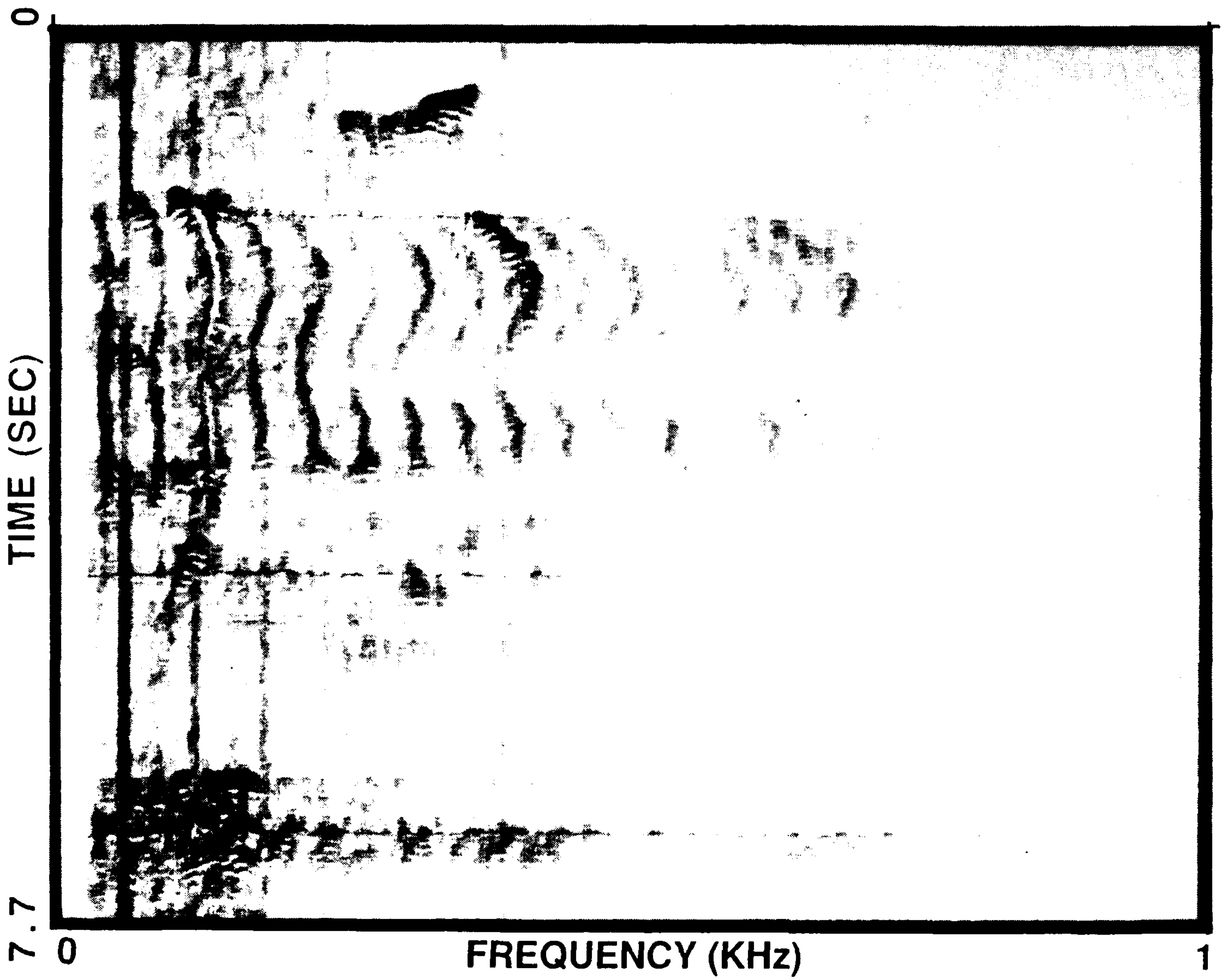




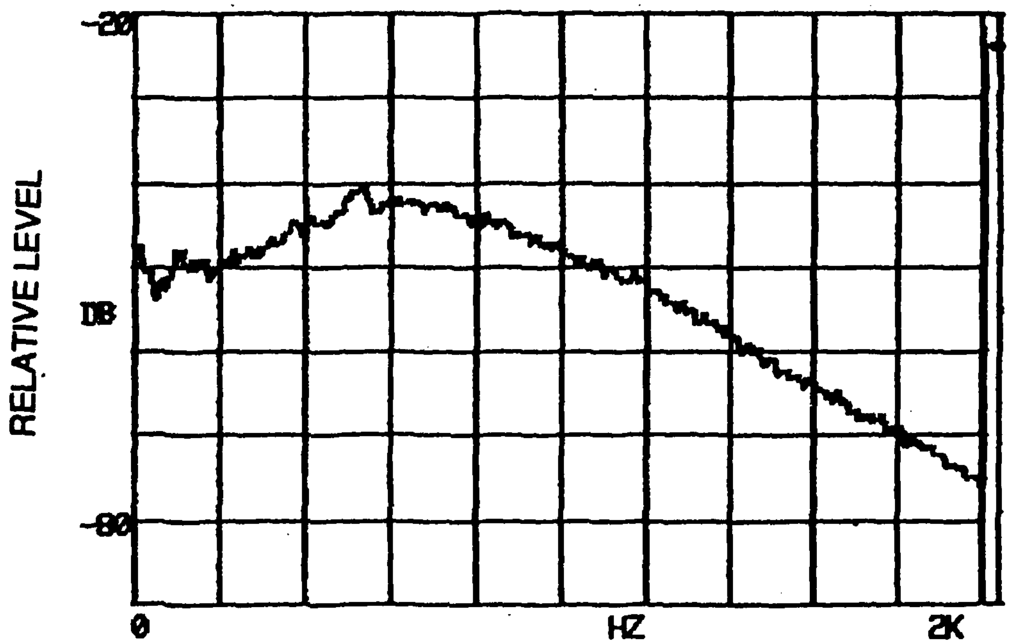
Ice, average spectrum of snow pelting (13.5 Hz calibration tone, 2.5 sec., above), same log scale (below). AFB-75 Hz

TRANSIENT DATA

SUBJECT	**Wave Slap**
DATE	May 1982
LOCATION	11 km E of Point Barrow, Alaska
CONDITIONS	Hydrophone on edge of open, 2 km lead, near grounded ice ridge, 19 m water depth. Northerly wind, 21 mph. Hydrophone at middepth, remotely sensed. Temperature -3 deg C.
TRANSIENT DESCRIPTION	Wave slap phenomena are well known and have been described by numerous authors, e.g., Dyer, Diachok, Milne. The cause of this transient is water waves impacting the ice wall. These are wind-driven waves. This is probably the most common source of natural physical transients in the MIZ under conditions of high winds from effective bearings, open water, and ice walls. Although evidence of this transient can be seen up to and beyond 20 kHz, the most effected band in the data presented here was at 0.2-1 kHz. Individual slaps were up to 40 dB over the prevailing ambient noise at the effective frequency bands. The downward slope was 25 dB/octave.
DATA SOURCE	W.C. Cummings, O. Diachok, many other investigators
SERIAL	**IWS**



NO. RIGHT WHALE MOANS (AFB-3.75 Hz)



Ice, average spectrum of wave slaps (27.7 sec.). AFB-7.5 Hz

IV. CONCLUSIONS AND RECOMMENDATIONS

A. AVAILABILITY OF DATA

This survey indicated that available information concerning biological and natural physical acoustic transients in Arctic regions is inadequate. This stems mainly from the paucity of data, which in turn suffers some inadequacies in quality and supporting environmental measurements.

This catalog was not intended to be exhaustive. Because of the limited level of support, we could not seek out all sources of data known to exist, especially in the case of physical transients. One of the problems, with that category of underwater noise was the availability of magnetic tape records for analysis, especially data collected with equipment of suitable frequency response. In some cases, available records were recorded for totally different purposes by using specified bandwidths to optimize received signals that were unrelated to endemic natural Arctic underwater acoustic transients. The frequent use of high- or low-pass filters, notch filters, or one-of-a kind recorders optimized the receiving instrumentation and improved signal-to-noise characteristics for the signals being studied, but they did little for, or totally eliminated, the fidelity to reproduce broadband physical transients. Nevertheless, more data sources are available than could be included here.

The availability of biological transient data was more encouraging, but these records are far from complete. In some cases we were unable to obtain copies of recordings that are known to exist, with the available resources.

Only a relatively few bioacoustical investigators have worked in Arctic regions, and much of the work was done 10 to 30 years ago. Most bioacoustic recordings were made with uncalibrated instruments. Consequently, source levels are known for only about half of the species. For some, there are no recorded data. With few exceptions, *e.g.*, the bowhead and finback whales, the durations of most available recordings are too brief to uncover individual animal, seasonal, or geographic differences. Many recordings of Arctic biological transients

were made on an opportunistic basis, the studies lacking sufficient support to have allowed the investigators enough time in any one location or repeated expeditions to areas of interest.

B. OCCURRENCE OF ARCTIC TRANSIENTS

Biological Transients

This survey showed that Arctic and sub-Arctic marine mammal species produce a wide variety of underwater transient noises whose time and spectral constants vary considerably. The most important independent variables involve concurrent animal behavior, which in many cases is a seasonal function. Geographic location is an important independent variable for migrant species. For these animals, behavior at the time of sound production may be highly correlated with geographic position. Arctic marine mammals must have access to open water for survival. Their sound occurrence offers clues to the nature of the sea's surface.

Bowhead whales produce monotonous repertoires of "songs" in the higher latitudes of their range during spring time. Bowhead songs may completely dominate the underwater noise for days at a time. Because of high source levels, this noise can saturate an area 15-km diameter. Bowhead utterances also include nonrepetitive sounds resembling powerful grunts and moans.

Beginning in March and continuing into May and the first part of June, the long wailing trills of bearded seals often dominate the underwater noise in the spectrum from 0.2 to 5 kHz. The duty cycle of a single trill may be 2 min. We have encountered as many as six high signal/noise trills at once, each in different regions of the affected 5-kHz spectrum. Along with other less powerful background trills, too numerous to count, the masking factor of this single category of transient is significant in widespread Arctic regions for about a fourth of the year.

The bearded seal is one of the most numerous marine mammals in circumpolar regions. Although this species is not noted for an ability to create, or keep open, access holes in the ice, its northward distribution extends well into the pack ice. The occurrence of its sounds signifies the existence of at least limited, naturally opened ice, and a possible access for the seal through open water.

On the other hand, ringed seals, the most numerous Arctic marine mammal, can make and keep open access holes through the ice. They

reportedly are distributed to the pole itself. Unlike bearded-seal sounds, once detected under pack ice, ringed-seal sounds would not necessarily indicate regions of naturally opened access. Except for the spring pupping and breeding season, ringed-seal sounds are not as common as those of bearded seals.

This survey revealed the different needs of Arctic seal species during various stages of their life cycles. Their transient sounds indicate the animals' locations and something about environmental conditions. The same is true of the whales, although compared to pinnipeds, as a group, their association with Arctic ice is more limited.

Transient sounds from large whales signify proximity to open water or to newly formed ice less than 12-cm thick. The sounds of some species, *e.g.*, the humpback whale, are indicative of major open water areas. This species has no proclivity for ice. Due to available food resources, and other requirements, it may only occur near it.

On the other hand, the bowhead whale is pagophylic or "ice-loving". Its sounds will signal leads, polynyas, or thin ice generally within a radius of less than 1 km.

Surprisingly, bowhead whales may transit under heavy ice. They have an uncanny ability to detect regions with enough open water or thin ice within the maximum underwater swimming distance of about 5 km before they must surface to breathe. Natural drownings presumably do occur, but, considering the low reproduction potential of bowhead whales (no more than one calf every 2 to 3 years) and other mortality factors, such catastrophes must be rare or the species would never have survived. Once the decision is made to venture beneath heavy ice, the bowhead whale has a maximum of about 30 min turn-around time to return to its former source of air. Eskimos say that harpooned whales, in their attempt to escape under solid ice, have died there, their putrefying bodies rising to the bottom ice surface.

Since bowheads are so loquacious and their position in heavy ice is tenuous at best, the hypothesis is suggested that they may use sonar by processing passive acoustic transients, *e.g.*, surface wave slap, or by processing surface reverberation characteristics of their own transient sounds.

Mysticete whale (having baleen, instead of teeth) transients are characteristically powerful, low-frequency (Hz) utterances, chiefly

below 5 kHz, with fundamentals below 200 to 500 Hz. Peak spectrum source levels may be as high as 190 dB. Typical of their sounds are pulsed or swept frequency moans with a simple or complex structure. Bowhead whales produce raucous, low-frequency (Hz) wailing sounds resembling cries or screams.

Odontocete whales (those with teeth, instead of baleen) characteristically produce broadband click trains and relatively pure tone sinusoids (whistles), often simultaneously. Affected regions of the spectrum may be as high as 150 kHz. Experimental data clearly show that, in the species investigated, e.g., dolphins, killer whales, and belugas, there is a well-developed, high-resolution, active sonar capable of accommodating to changing environmental acoustic conditions.

Dolphins compensate for changes in ambient level, and can avoid noisy regions of the ambient spectrum by shifting frequency (Hz) of their pulse trains and by beamforming. They are experts at overcoming problems with reverberation.

Although this report also includes data on other Arctic odontocetes, the two most commonly found nearest or under the ice are the beluga and the narwhal; they epitomize the pagophylics. In fact, large herds comprised of up to thousands of belugas often precede the arrival of bowheads in heavily ice-covered waters. After surveying areas by aircraft, one of us (WCC) has recorded beluga sounds in regions thought to be entirely covered with solid ice, so much that bowhead and most seal sounds had been absent for periods up to 24 hrs. Evidently, belugas have an unusual ability to "read" the ice.

Physical Transients

I. Dyer, B. Buck, and their associates; R. Pritchard; A. Milne; R. Mellon; H. Kutschale; and others included in the provided list of Selected References, have analyzed the occurrence of certain physical transients over variable time periods in specific locations. We also obtained some of these data. Some generalized observations on their occurrence follow.

Thermal ice-stress acoustic events are broadband impulses resulting from changes and the rate of change in ambient air temperature. Sudden temperature decreases trigger these sounds to occur in response to changes of thermal stress in the ice. The occurrence of

noise sources depends upon the frequency of crustal movements. Dynamic, compressional stress transient noises are most common in active areas of the ice sheet, such as margins of refrozen fractures or leads, in ridge building areas, or at the boundaries of moving large ice masses. Brine drip noises may occur in midwinter, but they are frequent during spring thaws in the MIZ.

Repeated squeaking noises occur from the constant rubbing of ice plates on one another in response to out-of-phase movements. Collision transient noises depend on the availability of open water and floating moving ice masses of variable dimensions from centimeters to tens of meters. Consequently, the occurrence of collision transients is most highly correlated with the existence of leads, polynyas, and currents, wind shifts, or other causes of moving ice in open water.

Compared with choruses of biological transients, physical transients generally have a lower frequency of occurrence/time period. Moreover, their duty cycles are generally shorter than those of animal sounds. For example, the duration of a particular category of blue whale sound is 37 sec and an individual may repeat it for hours. The cacophony of squeals and whistles from large beluga herds may continue for weeks in a single location. An exception may be rhythmic, ice-squeaking bouts, such as those WCC and coworkers recorded in the area of contiguous ice plates in marginal ice off Barrow, Alaska. Tonals from ridges may also be protracted. Surface water waves set the plates into rocking motions. The resulting high-level squeaking transients continued for seven days until increased wind moved the plates apart.

Certain categories of ice-related acoustic transients may signify ice conditions. For example, the rumbling acoustic transients of ridge building and destruction processes are fairly definitive. Their sounds indicate the presence of ridges. The bumping and knocking noises from colliding small ice masses signify open water, as do wave slap transients. We made no attempt to summarize the statistics of transient occurrence; however, the reader is urged to see the original reports, many of which are listed in the SELECTED REFERENCES section.

C. RECOMMENDATIONS

As a result of this provisional survey of Arctic acoustical transients, we offer the following recommendations:

(1) The apparent brevity of suitable recordings of physical Arctic transients warrants more and better data. We need longer recorded periods with instruments of optimal frequency response and low internal noise. One solution involves an ability to isolate responsible mechanism(s) in the natural environment, calling for transient sound localization. Another is to measure supporting independent mechanisms on a relatively long-term basis. Only in this way will it be possible to understand the causes and mechanisms of physical acoustic transients. Some studies, *e.g.*, those under Marginal-Ice-Zone-Experiment (MIZEX) support, have occurred in an integrated fashion, with excellent results.

(2) Previous Arctic bioacoustic investigations were primarily under Navy sponsorship. Examples of these investigations are the pioneering efforts of W. Schevill, W. Watkins, and C. Ray. However, research aims of sponsoring research and development (R & D) groups have undergone change in the past decade or so. Either more funding should be available to support basic bioacoustic research in the Arctic or substitute support should be made available to the technically capable bioacousticians with Arctic experience.

Much remains to be done on bioacoustic sources. For example, we are unaware of any recordings of the sei whale, or from the goosebeak and the North Pacific giant bottlenose whales, near the Arctic or elsewhere. We know of only two brief recordings from the North Atlantic bottlenose whale. Except for some of the recent work on bearded and ringed seals, recordings from the 10 pinniped species are incomplete from the standpoints of season, duration, geography, and fidelity. Much the same can be said of the 5 porpoises that frequent Arctic regions. Among the large whales, only the bowhead has been recorded over significant time periods in Arctic waters. Most sounds of mysticetes that frequent the Arctic were recorded in temperate waters, or in lower latitudes.

(3) In addition to obtaining badly needed new recordings and associated acoustic data on both physical and biological Arctic transients, we recommend that this review be expanded. One reason would be to fulfill the military's increasing need for such data. For several species, there are sufficient recordings of suitable quality to further

analyze signals for the characteristics of most interest. Only a small sample of natural physical transients could be included under the present level of support. More of these data exist, and they also should be included. We are aware of other sources of recordings that may contain valuable information on Arctic transients, but for the most part have never been analyzed for such information. Our own databases contain a collection of man-made Arctic transient recordings, but these too had to be left out of the present effort. All identified transients of interest should be analyzed by using military hardware. Performance evaluations are needed.

(4) The typical acoustical environment of ice-covered waters is influenced most by upward refraction in the water column and downward reflection and backscatter from the canopy's underside. We have identified some species that we suspect have learned to cope with the peculiarities of such an environment. Namely, that passive, and perhaps active, sonar possibly are connected with the bowhead whale, beluga, narwhal, and ringed seal's apparent abilities to somehow "read" the ice from significant distances. Other species are well adapted for their Arctic existence. We recommend that a critical study be made of their sound's waveforms and spectral characteristics, the temporal and frequency (Hz) changes in series of transients, and their autocorrelation functions. Comparisons of sounds produced under ice and under open water may offer some clues to this apparent adaptation.

(5) As the database of natural and physical MIZ acoustic transients increases, a corresponding need exists for better methods of identification and classification. Even the most experienced acousticians have difficulty with such identifications. The time has arrived for automated classification of bioacoustical transients to augment other developing transient acoustic processing. One such possibility lies with the promise of artificial neural-network signal processing because of its ability to handle highly variable factors.

V. SELECTED REFERENCES

BOGORODSKII, V. V. and A. V. Gusev (1969) Under-Ice Noise in the Ocean. Sov. Phys. Acoust., 14, 127-134.

BUCK, B. M. (1968) Arctic Acoustic Transmission Loss and Ambient Noise. In: Arctic Drifting Ice Stations, J. E. Sater, ed., Arctic Inst. No. America, 427-438.

BUCK, B. M., J. H. Wilson (1986) Nearfield Noise Measurements from an Arctic Pressure Ridge. J. Acoust. Soc. Amer., 80, 256-264.

BUSNEL, R.G. and J. F. Fish, eds. (1980) Animal Sonar Systems. Plenum Press, 1135 pp.

BUSNEL, R. G. and A. Dziedzic (1966) Acoustic Signals of the Pilot Whale *Globicephala melaena* and of the porpoises *Delphinus delphis* and *Phocoena phocoena*. In: Whales, Dolphins, and Porpoises, K. S. Norris, ed., University of California Press, Berkeley, 607-646.

CLAY, C.S. and H. Medwin (1977) Acoustical Oceanography: Principles and Applications. J. Wiley & Sons, N.Y., London, Sydney, and Toronto, 544 pp.

CUMMINGS, W.C. (1988) Passive Acoustics of Marine Animals. In: Biology and Target Acoustics of Marine Life: a Workshop. J.W. Foerster, ed., Report of ONR and U.S. Naval Academy, Annapolis, MD, 206 pp.

CUMMINGS, W.C. (In Press) Arctic Acoustics and Vibration: A Summary. Proceedings of a Meeting of Comite' Arctique Internationale, U. of Alaska, Fairbanks, AK, July 1985, 41 pp.

CUMMINGS, W.C. (1988) Natural Arctic MIZ Acoustic Transients (U) (Uncl). p 11.1-11.22 in: Proceedings of the Transient Technological Review and Workshop, 17-19 June 1987 (U). R. Tozier, ed. NUSC Tech. Document 8285, 14 Apr 1988, 630 pp (Secret).

CUMMINGS, W.C. (1975) Unique IFF (U). In: Proceedings of Underwater Sound Advisory Group, Minisymposium on Underwater Acoustic Communications, 20-21 Nov. 1974. Naval Undersea Center, San Diego, 00S-1090-75, 315 pp (Secret).

CUMMINGS, W.C. (1980) Project COMBO: Review and Recommendations (U). Naval Ocean Systems Center, San Diego, TR 422, 68 pp (Secret).

CUMMINGS, W.C., W.T. Ellison, and D.V. Holliday (1981) Environmental Noise Studies in the Arctic. Northern Engineer, U. of Ak, 13, 14-20.

CUMMINGS, W.C., D.V. Holliday, B.J. Graham, and W.T. Ellison (1981) Underwater Sound Measurements from the Prudhoe Region, Alaska, September-October 1980. Tracor (San Diego, CA) T-81-SD-001-U, 50 pp.

CUMMINGS, W.C. and D. V. Holliday (1985) Passive Acoustic Location of Bowhead Whales in a Population Census off Pt. Barrow, Alaska. J. Acoust. Soc. Am., 78, 1163-1169.

CUMMINGS, W.C. and D.V. Holliday (1987) Sounds and Source Levels from Bowhead Whales off Pt. Barrow, Alaska. J. Acoust. Soc. Am. 82, 814-821.

CUMMINGS, W. C., D. V. Holliday, and B. J. Lee (1984) Potential Impacts of Man-made Noise on Ringed Seals: Vocalizations and Reactions. Tracor (San Diego, CA) T-84-06-008-U, 124 pp.

CUMMINGS, W. C., P. O. Thompson (1971) Underwater Sounds from the Blue Whale, *Balaenoptera musculus*. J. Acoust. Soc. Am., 50, 1193-1198.

CUMMINGS, W. C., P. O. Thompson, and R. Cook (1968) Underwater Sounds from Migrating Gray Whales, *Eschrichtius glaucus* Cope. J. Acoust. Soc. Am., 44, 1278-1281.

CUMMINGS, W.C., P.O. Thompson, and S.J. Kennison (1978) Sonarman's Guide to Biologics. Naval Ocean System Center TD 181, 168 pp (Confidential).

DAHLHEIM, M. E. and F. Awbrey (1982) A Classification and Comparison of Vocalizations of Captive Killer Whales (*Orcinus orca*). J. Acoust. Soc. Am., 72, 661-670

DENKER, J.S. (1986) AIP Conference Proceedings, Neural Networks for Computing. American Institute of Physics, Snowbird, Utah, 273 p.

DIACHOK, O. I. (1976) Effects of Sea-Ice Ridges on Sound Propagation in the Arctic Ocean. J. Acoust. Soc. Amer., 59, 1110-1120.

DIACHOK, O. I. (1980) Arctic Hydroacoustics. Cold Regions Sci. Tech., 2:299-321.

DIACHOK, O. I. and G. K. Long (1974) Sources of Ambient Noise in the Shallow-water Marginal Ice Zone. SACLANTCEN Conference Proceedings 14, 141-155.

DIACHOK, O. I. and R. S. Winokur (1974) Spatial Variability of Underwater Ambient Noise at the Arctic Ice-water Boundary. J. Acoust. Soc. Amer., 55, 750-753.

DUBROVSKII, N. A., P. S. Krasnov and A. A. Titov (1970) On the Emission of Echolocation Signals by the Azov Sea Harbor Porpoise. Akusticheskii Zhurnal, 16, 521-525. Eng. Transl. in Soviet Physics-Acoustics, 16, 444-447.

DWYER, R. F. (undated) Arctic Ambient Noise Statistical Measurement Results and Implications to Sonar Performance Improvements. SACLANTCEN CP 32, 7-1 TO 7-10.

DWYER, R. F. (1982) Arctic Ambient Noise Statistical Measurement Results and their Implications to Sonar Performance. NUSC Reprint Report 6739.

DWYER, R. F. (1983) A Technique for Improving Detection and Estimation of Signals Contaminated by Under Ice Noise. J. Acoust. Soc. Amer., 74, 124-130.

DYER. I. (1981) Low Frequency Ambient Noise in the Deep Arctic Ocean. J. Acoust. Soc. Amer., 69, Suppl. 1, H3.

DYER, I. (1984) The Song of Sea Ice and other Arctic Ocean Melodies. In: Arctic Technology and Policy, I. Dyer and C. Chryssostomidis, eds., Hemisphere Publ. Corp., Washington, N.Y., and London, 11-37.

DYER, I. and A. B. Baggeroer (1981) FRAM II Ambient Noise Data. J. Acoust. Soc. Amer., Suppl. 1, H11.

DYER, I., J. Mccoy, J. M. McKisic, R. Obrochta, and R. Spindel (1984) The Arctic ASW Special Focus Program, a Five Year Management Plan for Fiscal Years 1985 to 1989. Report by ONR, Arlington, VA, 110 pp.

EDDS, P. L. (1981) Variations in Vocalizations of Fin Whales, *Balaenoptera physalus*, in the St. Lawrence River. M.S. Thesis, Univ. of Maryland, College Park, 126 pp.

EDDS, P. L. (1982) Vocalizations of the Blue Whale, *Balaenoptera musculus*, in the St. Lawrence River. J. Mammalogy, 63, 345-347.

ELLIS, R. (1980) The Book of Whales. A.A. Knopf, New York, 202 pp.

FISH, J. F. and J. S. Vania (1971) Killer Whale, *Ocinus orca*, Sounds Repel White Whales, *Delphinapterus leucas*. Fish. Bull., 69, 531-535.

FORD, J. K. B. and H. D. Fisher (1978) Underwater Acoustic Signals of the Narwhal (*Monodon monocerus*). Can. J. Zool., 56, 552-560.

FORD, J. K. B. and H. D. Fisher (1982) Killer Whale (*Ocinus orca*) Dialects as an Indicator of Stocks in British Columbia. Rep. Int. Whaling Comm., 32, 671-679.

GANTON, J. H. and A. R. Milne (1965) Temperature and Wind-dependent Ambient Noise Under Mid-Winter Pack Ice. J. Acoust. Soc. Amer., 38, 406-411.

GREENE, C. R. and B. M. Buck (1964) Arctic Ocean Ambient Noise. J. Acoust. Soc. Am., 36, 1218-1220.

GUREVICH, V. S. and W. E. Evans (1976) Echolocation Discrimination of Complex Planar Targets by the Beluga Whale (*Delphinapterus leucas*). J. Acoust. Soc. Am., 60, Suppl. 1, 55-56.

HOLLIDAY, D. V., W. C. Cummings, and W. T. Ellison (1980) Underwater Sound Measurements from Barrow and Prudhoe Regions, Alaska, May-June, 1980: a Report Submitted to the Alaska Eskimo Whaling Commission. Tracor (San Diego, CA) No. T-80-SD-022-U, 316 pp.

HOLLIDAY, D.V. and W.C. Cummings, (1985) Spatial Distribution of Discrete Noise Sources under Arctic Ice. J. Acoust. Soc. Am. Suppl. 1, 77, S56-S57.

HOPFIELD, J.J. and D.W. TANK (1986) Computing with Neural Circuits: a Model. Science 233, 629.

JOHNSON, G. L., D. A. Horn, O. M. Johannessen, S. Martin, and R. D. Muench (1985) MIZEX. Sea Technology, May, 18-22.

KING, J. E. (1964) Seals of the World. Publ. of the Brit. Mus. (Natural History), 154 pp.

KUTSCHALES, H. (1969) Arctic Hydroacoustics. Lamont-Doherty. Geo Obs. Columbia U., Arctic, 22, 246-264.

LEATHERWOOD, S., W. E. Evans, and D. W. Rice (1972) The Whales, Dolphins, and Porpoises of the Eastern North Pacific: a Guide to their Identification in the Water. Naval Undersea Center (NOSC, San Diego, CA), NUC TP 282, 175 pp.

LJUNGBLAD, D. K., P. O. Thompson, and S. E. Moore (1982) Underwater Sounds Recorded from Migrating Bowhead Whales, *Balaena mysticetus*, in 1979. J. Acoust. Soc. Am., 71, 477-482.

MACPHERSON, J. D. (1962) Some Under-Ice Ambient Noise Measurements. J. Acoust. Soc. Amer., 34, 1149-1150.

MAKRIS, N. C. and I. Dyer (1986) Environmental Correlates of Pack Ice Noise. J. Acoust. Soc. Amer., 79, 1434-1440.

McGRATH, J. R. (1976) Depth and Seasonal Dependence of Ambient Noise Near the Marginal Ice Zone of the Greenland Sea. Naval Research Laboratory, Washington D.C., Report 7819.

MELLEN, R. H. (1966) Underwater Sound in the Arctic Ocean. U. S. Navy J. Underwater Acoustics, 16, 247-259, 419-426.

MELLEN, R. H., H. W. Marsh (1965) Underwater Sound in the Arctic Ocean. AVCO Marine Electronics Office Report submitted to USL.

MITCHELL, E. D. (ed.) (1975) Special Issue- Review of Biology and Fisheries of Smaller Cetaceans, Report and Papers from a Meeting of the Subcommittee on Smaller Cetaceans, International Whaling Commission, in Montreal, April 1-11, 1974. J. Fish. Res. Bd. Canada, 32, 889-1242.

MOHL, B and S. Andersen. (1973) Echolocation: High-Frequency Component in the Click of the Harbor Porpoise (*Phocoena ph.* L.). J. Acoust. Soc. Am., 54, 1368-1372.

MOHL, B. and K. Ronald (1968) Sound Recordings of the Harp and Hood Seal (a). Biol. Sonar and Diving Mammals, Stanford Res. Inst., CA, 68.

PAYNE, K. and R. Payne (1985) Large Scale Changes over 19 years in Songs of Humpback Whales in Bermuda. Z. Tierpsychol., 68, 89-114.

RAY, G. C., W. A. Watkins, and J. J. Burns (1969) The Underwater Song of *Erignathus* (bearded seal). Zoologica, 54, 79-83.

RAY, G. C. and W. A. Watkins (1975) Social Function of Underwater Sounds in the Walrus *Odobenus rosmarus*. Rapp. P.-v. Reun. Con Int. Explor. Mer, 169, 524-526.

REEVES, R. R. and R. L. Brownell, Jr. (1982) Baleen Whales- *Eubalaena glacialis* and Allies. In: Wild Mammals of North America, Biology, Management, and Economics, J. A. Chapman and G. A. Feldhamer, eds., Johns Hopkins University Press, Baltimore, 415-444.

RIDGWAY, S. H. and Sir Richard Harrison, eds., (1981) Handbook of Marine Mammals, Vol. 1, the Walrus, Sea Lions, Fur Seals and Sea Otter. Academic Press.

RIDGWAY, S. H. and Sir Richard Harrison, eds., (1981) Handbook of Marine Mammals, Vol. 2, Seals. Academic Press.

RIDGWAY, S. H. and Sir Richard Harrison, eds., (1985) Handbook of Marine Mammals, Vol. 3, the Sirenians and Baleen Whales. Academic Press, 362 pp.

ROSS, D. (1976) Mechanics of Underwater Noise. Pergamon Press, New York, 375 pp.

SCAMMON, C. M. (1874) The Marine Mammals of the North-Western Coast of North America, Described and Illustrated: Together with an Account of the American Whale-Fishery. John H. Carmany and Company, San Francisco; G. P. Putnam's Sons, N. Y., 319 pp.

SCHEVILL, W. E. (1964) Underwater Sounds of Cetaceans. In: Marine Bioacoustics, W. N. Tavolga, ed. Pergamon Press, 307-316.

SCHEVILL, W. E. and W. A. Watkins (1962) Whale and Porpoise Voices. Woods Hole Oceanographic Inst. (with phonographic record), 24 pp.

SCHEVILL, W. E., W. A. Watkins, and R. H. Backus (1964) The 20-Cycle Signals and (*Balaenoptera).* In: Marine Bioacoustics, W.N. Tavolga, ed. Pergamon Press, 147-152.

SCHEVILL, W. E., W. A. Watkins, and C. Ray (1966) Analysis of Underwater *Odobenus* Calls with Remarks on the Development and Function of the Pharyngeal Pouches. Zoologica, 51, 103-106.

SCHUSTERMAN, R. J., R. F. Balliet, and S. St. John (1970) Vocal Displays Under Water by the Gray Seal, the Harbor Seal, and the Steller Sea Lion. Psychonomic Science, 18, 303-305.

SCORESBY, W. (1820) An Account of the Arctic Regions with a History and Description of the Northern Whale-Fishery, Vol. 2: The Whale Fishery. Archibald Constable and Co. Edinburgh and Hurst, Robinson and Co., Cheapside, London, 574 pp, 22 plates.

SONAFRANK, N. R., R. Elsner, and D. Wartzok (1983) Under-Ice Navigation by the Spotted Seal, *Phoca largha* (a). 5th Biennial Conf. on Biol. Mar. Mammals, Boston, MA, Nov. 1983.

STIRLING, I. (1973) Vocalization in the Ringed Seal (*Phoca hispida*). J. Fish. Res. Bd. Can., 30, 1592-1594.

TAVOLGA, W. N. (1965) Review of Marine Bio-Acoustics, State of the Art:1964. NTRADVC (Orlando, FL), Report 1212-1, 100 pp.

TERHUNE, J. M. and K. Ronald (1973) Some Hooded Seal (*Cystophora cristata*) Sounds in March. Can. J. Zool., 51, 319-321.

THOMPSON, P.O., W.C Cummings, and S.J. Ha (1986) Sounds, Source Levels, and Associated Behavior of Humpback Whales, Southeast Alaska. J. Acoust. Soc. Am., 80, 735-740.

URICK, R.J. (1983) Principles of Underwater Sound. McGraw-Hill Book Co., 423 pp.

WALKER, K.D., convenor (1988) Acoustic Transient Workshop (U) 15-18 March 1988, CMDR Patrol Wing Eleven, Jacksonville, FLA, with 6 encl, 495 pp (Secret).

WARTZOK, D. J., J. Gailey-Phipps, N. Schultz, and J. C. Beier (1981) Vocalizations of Captive Spotted Seals, *Phoca largha* (a). 4th Biennial Conf. on the Biol. of Mar. Mammals, San Francisco, CA.

WATKINS, W. A. and G. C. Ray (1977) Underwater Sounds from Ribbon Seal, *Phoca (Histriophoca) fasciata*. Fish. Bull., 75, 450-453.

WATKINS, W. A. and W. E. Schevill (1977) Sperm Whale Codas. J. Acoust. Soc. Am., 62, 1485-1490.

WATKINS, W. A. and W. E. Schevill (1979) Distinctive Characteristics of Underwater Calls of the Harp Seal, *Phoca groenlandica*, During the Breeding Season. J. Acoust. Soc. Am., 66, 983-988.

WATKINS, W. A., W. E. Schevill, and C. Ray (1971) Underwater Sounds ot *Monodon* (narwhal). J. Acoust. Soc. Am., 49, 595-599.

WINN, H. E. and P. J. Perkins (1976) Distribution and Sounds of the Minke Whale, with a Review of Mysticete Sounds. Cetology, 19, 12 pp.

WINN, H. E., P. J. Perkins, and L. Winn (1971) Sounds and Behavior of the Northern Bottle-Nosed Whale. SRI (Menlo Park, CA), Proc. 7th Ann. Conf. on Biological Sonar and Diving Mammals, 53-59.

WINN, H. E., T. J. Thompson, W. C. Cummings, J. Hain, J. Hudnall, H. Hays, and W. W. Steiner (1981) Song of the Humpback Whale-Population Comparisons. Behav. Ecol. Sociobiol., 8, 41-46.

VI. INDEX

BIOLOGICAL TRANSIENTS

NATURAL PHYSICAL TRANSIENTS